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Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{13}	tera	T	tēr'a
10^9	giga	G	jī'ga
10^6	mega	M	mēg'a
10^3	kilo	k	kī'lo
10^2	hecto	h	hēk'to
10	deka	da	dēk'a
10^{-1}	deci	d	dēs'i
10^{-2}	centi	c	sēn'ti
10^{-3}	milli	m	mī'l'i
10^{-6}	micro	μ	mī'kro
10^{-9}	nano	n	nān'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fēm'to
10^{-18}	atto	a	āt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å.....	angstrom.....	10^{-10} meter
a.....	annum, year	
BeV.....	billion electron volts.....	GeV
Ci.....	curie.....	3.7×10^{10} dps
cm.....	centimeter(s).....	0.394 inch
cpm.....	counts per minute	
dpm.....	disintegrations per minute	
dps.....	disintegrations per second	
eV.....	electron volt.....	1.6×10^{-12} ergs
g.....	gram(s)	
GeV.....	giga electron volts.....	1.6×10^{-3} ergs
kg.....	kilogram(s).....	1,000 g = 2.205 lb.
km ²	square kilometer(s)	
kVp.....	kilovolt peak	
m ³	cubic meter(s)	
mA.....	milliampere(s)	
mCi/mi ²	millicuries per square mile.....	0.386 nCi/m ² (mCi/km ²)
MeV.....	million (mega) electron volts.....	1.6×10^{-6} ergs
mg.....	milligram(s)	
mi ²	square mile(s)	
ml.....	milliliter(s)	
mm.....	millimeter(s)	
nCi/m ²	nanocuries per square meter.....	2.59 mCi/mi ²
pCi.....	picocurie(s).....	10^{-12} curie = 2.22 dpm
R.....	roentgen	
rad.....	unit of absorbed radiation	
	dose.....	100 ergs/g

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RADIATION DATA AND REPORTS

Volume 13, Number 11, November 1972

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

Environmental Radioactivity in Illinois, 1970

Moshe J. Shmuklarsky¹

The contribution of radioactivity to the Illinois environment during 1970 resulting from the operation of nuclear power plants and from other major natural and manmade sources is presented. The environmental surveillance programs of the Dresden, Quad-Cities and Zion nuclear power stations are described. Dresden Unit 1 radioactive gaseous and liquid releases for the past 11 years, and Dresden Unit 2 discharges for 1970 are summarized. On the basis of data gathered during 1970, it is concluded that the effect of nuclear power plant operations on the radioactivity level of most environmental media was hardly distinguishable from the natural and fallout radioactivity. The only measured environmental radiation effect of nuclear power generation within the State was an apparent increase of a few millirem per year in the external background exposure in the vicinity of Dresden-1.

The many sources of radioactivity in the environment may lead to population exposure through a variety of direct and indirect pathways. In order to estimate population dose from environmental radiation, it is necessary to identify and quantify the concentration of radionuclides in each exposure pathway. Knowledge of the sources and pathways of environmental radiation is the first step in the control, reduction and possible prevention of unnecessary population exposure.

By far the greatest source of radiation exposure to the population is natural background radiation from cosmic rays and from terrestrial, gamma-emitting, naturally-occurring radionuclides. These sources do not lend themselves to control, but because of their variability with time and place, it is essential to monitor them in order to detect any contribution that may arise from manmade, controllable, sources of environmental radiation.

Medical x rays are the greatest controllable

source of population exposure. However, the benefit to the patient from the diagnostic procedure usually outweighs the risk from exposure to radiation. Generally, the use of radiation in the healing arts is not classified under environmental radiation per se.

Nuclear facilities represent one source of environmental radiation which is amenable to controls; hence, it is appropriate to assess the contribution of this source to population dose. Releases of radioactivity from nuclear power operation contribute a small part of the total population exposure to ionizing radiation at present. Such releases, however, increasingly engage the concern of the environmentalists, the public health authorities, and the general public, particularly in light of the steady increase in number and output of nuclear power plants and ancillary facilities. A measure of the projected increase in nuclear power plants in the United States may be obtained from the following tabulation:²

¹ Mr. Shmuklarsky is with the Field Operations Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460.

² AEC News Release, March 31, 1972

	Number	Capacity (MW(e))
Plants operable -----	23	10,007
Plants being built ---	54	45,794
Planned (reactors ordered -----)	57	56,702
Total -----	134	112,503

For the purpose of gaining perspective with respect to population exposure, it is important to document such factors as: normal background radiation, radioactive releases to the environment, population distribution around reactor sites and vectors that bear upon radiation exposure to the population in the vicinity of nuclear power plants.

The State of Illinois had two nuclear power plants in operation during 1970; these were Dresden Nuclear Power Station, Units 1 and 2. Five other nuclear power plants were in vari-

ous stages of construction: Dresden Station Unit 3, Quad-Cities Station Units 1 and 2 and Zion Station Units 1 and 2. By 1973, seven nuclear power plants are scheduled to operate commercially in Illinois with a total annual generating capacity of 5,646 net megawatts electric. Table 1 summarizes the rated power output, ownership (1), and pertinent population data for these reactors and those in the planning stages. The locations of the reactor facilities are shown in figure 1.

During 1970, preoperational environmental monitoring programs were conducted around the Quad-Cities and the Zion sites. Data gathered in these programs will provide a base-line for measuring future changes in the environmental radiation around these facilities. In addition, the preoperational data also provide a basis for comparison with data obtained in the environmental monitoring program of the Dresden Station.

Table 1. Major nuclear power facilities in Illinois, 1970^a

Name of facility	Operator	Reactor type ^b	Rated power		Year of startup	Location	Population ^c		
			Net MW(e)	MW(t)			5 miles	10 miles	50 miles
Operating:									
Dresden 1	Commonwealth Edison Co.	BWR	210	700	1959	Morris	5,090	32,288	6,137,524
Dresden 2	Commonwealth Edison Co.	BWR	809	2,527	1970	Morris	5,090	32,288	6,137,524
Under construction:									
Dresden 3	Commonwealth Edison Co.	BWR	809	2,527	1971	Morris	5,090	32,288	6,137,524
Quad-Cities 1	Commonwealth Edison Co. & Iowa-Illinois Gas & Electric Co.	BWR	809	2,511	1971	Cordova	5,845	26,619	600,113
Quad-Cities 2	Commonwealth Edison Co. & Iowa-Illinois Gas & Electric Co.	BWR	809	2,511	1972	Cordova	5,845	26,619	600,113
Zion 1	Commonwealth Edison Co.	PWR	1,100	3,391	1973	Zion	46,196	190,314	7,150,792
Zion 2	Commonwealth Edison Co.	PWR	1,100	3,391	1973	Zion	46,196	190,314	7,150,792
Planned:									
Lasalle 1	Commonwealth Edison Co.-Iowa	BWR	1,078	3,293	1977	Seneca	720	8,901	943,027
Lasalle 2	Commonwealth Edison Co.-Iowa	BWR	1,078	3,293	1978	Seneca	720	8,901	943,027
Commonwealth Edison 1 (Comed west 1)	Commonwealth Edison Co.	PWR	1,100	3,425	1978	Not announced	Not available	22,595	975,832
Commonwealth Edison 2 (Comed west 2)	Commonwealth Edison Co.	PWR	1,100	3,425	1979	Not announced	Not available	22,595	975,832
Illinois Power Company 1	Commonwealth Edison Co.	PWR	800	Not available	Not available	Clinton	Not available	Not available	Not available
Summary			10,802	30,994			57,851	280,717	15,807,288

^a Based on reference (1) and personal communication from Dr. John C. Golden, staff radioecologist, Commonwealth Edison Co.

^b BWR, Boiling Water Reactor; PWR, Pressurized Water Reactor.

^c Based on 1970 census.

^d Estimated.

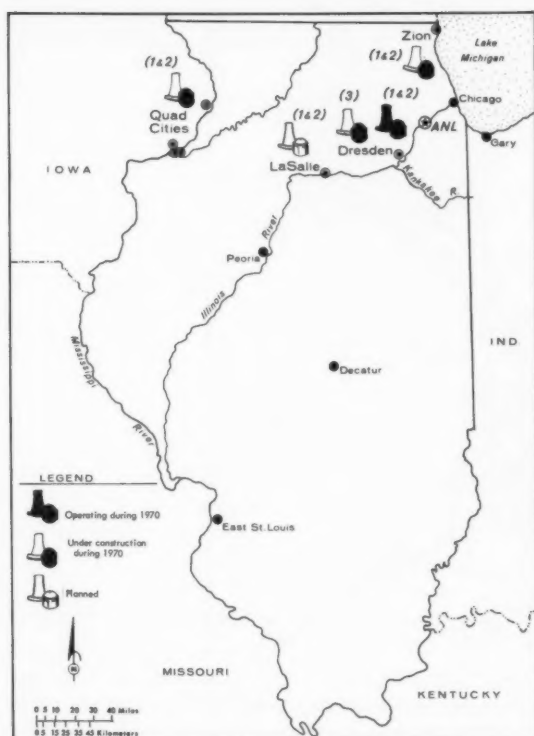


Figure 1. Location of reactor facilities

A variety of other environmental monitoring programs was in effect in the State. Routine statewide surveillance activities were conducted by the Illinois Department of Public Health, the Argonne National Laboratory (ANL) and the United States Environmental Protection Agency. The findings of these programs are published periodically in *Radiation Data and Reports* (2,3), ANL semiannual reports (4), and the Illinois Department of Public Health annual reports (5). In addition, a comprehensive survey of Lake Michigan, the source of condenser cooling water for the Zion Station as well as other nuclear power plants, was performed by the University of Michigan during 1969-1970 (6).

Dresden Nuclear Power Station

Environmental surveillance around nuclear power reactors

The Dresden Nuclear Power Station is located in Grundy County, Ill., where the Kankakee and Des Plaines Rivers merge to form the Illinois River. The site is 8 miles east of Morris, Ill. (1970 population total, 8,194) and approximately 50 miles southwest of Chicago. There are three boiling water reactors at the Dresden site. Unit 1 with a net electrical capacity of 210 megawatts has been in commercial service since August 1960. Unit 2, with a net electrical capacity of 809 megawatts, achieved criticality in January 1970 and was under a power test program for the remainder of the year. Unit 3, which is identical to Unit 2, was in the final stages of construction. Adjacent to and south of the Dresden Station is the Midwest Fuel Recovery Plant which also was in its final stages of construction during this period. The location of the Dresden Station in relation to the fuel recovery plant and the nearby communities and the environmental sampling locations are shown in figures 2 and 3.

Gaseous waste system

Dresden Unit 1 has a 300 foot stack through which the radioactive gaseous effluents are released into the atmosphere. Noncondensable radioactive isotopes of the noble gases, krypton and xenon, are removed from the primary coolant by an air ejector and exhausted into shielded piping which provides a holdup of 20 minutes for the decay of the short-lived isotopes of the noble gases. Before entering the stack, the gaseous effluents are filtered to remove the radioactive particulates resulting from neutron activation and decay of the noble gases. The relatively small quantity of radioactive gases from the turbine gland seal off-gas system is delayed for 2 minutes prior to discharge via the stack to provide sufficient decay time for the activation gases, nitrogen-16 (half-life, 7.4 seconds) and oxygen-19 (half-life, 29 seconds). Ventilation air from the reactor containment structure and the turbine building provides initial dilution in the stack before release of the effluents to the atmosphere.



Figure 2. General location of the Dresden Nuclear Power Station and nearby communities

Dresden Units 2 and 3 have identical gaseous waste systems with a 310 foot exhaust stack common to both units. Noncondensable radioactive gases from the primary coolant are delayed for 30 minutes and filtered by either of two parallel sets of particulate filters before being discharged via the stack. Radioactive gases from the turbine gland seal are held up for about 1.75 minutes before release. In addition, Units 2 and 3 have a vent stack for discharge of effluents originating in the reactor building. A more detailed description of the gaseous waste system in boiling water reactors in general, and the Dresden Units 1, 2, and 3 in particular, is given in references 7-10.

Prior to the operation of Dresden Units 2 and 3, the discharge limit for Unit 1 noble gas release rate was 0.7 curies per second. During 1970, with the anticipated power operations of Units 2 and 3, new limits were set by the Atomic Energy Commission (AEC). These limits account for the additive effect of simul-

taneous emissions of noble gases from the three discharge outlets at the Dresden Station. The release rates for the noble gases from all three sources onsite are guided by the formula:

$$\left[\frac{Q_1}{0.56} + \left(\frac{Q_{(2 \text{ or } 3)}}{0.7} \text{ or } \frac{Q_{(2 \text{ and } 3)}}{0.9} \right) + \frac{Q_{RS}}{0.09} \right] \leq 1 \dots (1)$$

Where:

- Q_1 = release rate from the stack of Unit 1 (Ci/s),
- $Q_{(2 \text{ or } 3)}$ = release rate from Units 2 and 3 stack (Ci/s) with only Unit 2 or 3 operating, but not both,
- $Q_{(2 \text{ and } 3)}$ = release rate from Units 2 and 3 stack (Ci/s) with both Units 2 and 3 operating, and
- Q_{RS} = release rate from Units 2 and 3 reactor building ventilation stack (Ci/s).

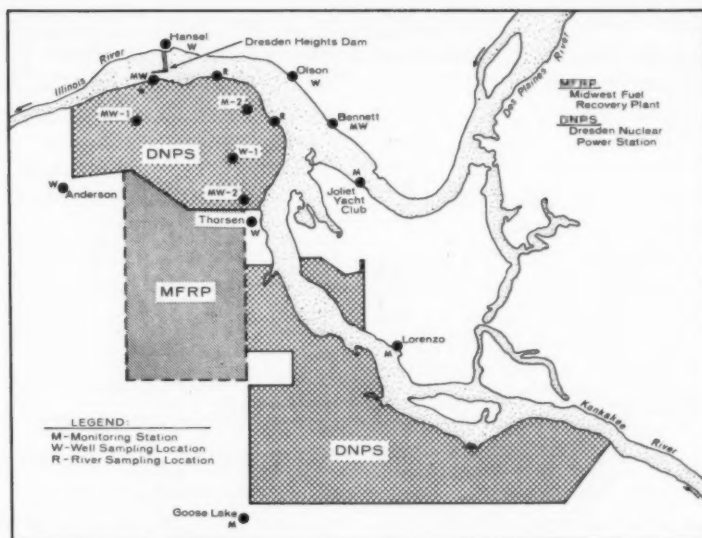


Figure 3. Monitoring and sampling locations

Similarly, the release limits for halogens and particulates were also adjusted in order to maintain concentration at the site perimeter within the original limits applied to the Dresden Unit 1. A formula similar to equation (1) is used to account for the additive effect of the discharges from the various outlets onsite.

Radioactive gaseous effluents

Radioactive gaseous effluents are generally classified as either noble and activation gases, which originate in the reactor core from fission and neutron activation, or halogens and particulates, which are mostly decay products of the short-lived isotopes of the noble gases with some being activation products. The rate of production of the radiogases is proportional to the plant's thermal output. Their release rate, however, is a function of factors such as fuel cladding, integrity, waste treatment system, waste management practices, etc. (11,12).

In a special study of the Dresden Unit 1 effluents by the Public Health Service (PHS) (9), the gaseous effluents were determined to be mostly short-lived noble gases. Since these noble gases are generally higher-energy gamma emitters, they are the major contributors to the whole body genetically significant dose in the vicinity of an operating boiling water re-

actor. However, in less than 2 days decay time after release, the dose from these radiogases decreases by at least two orders of magnitude (13). The longer-lived noble and activation gases detected during the special study were xenon-133 (9,000 Ci/a), krypton-85 (3 Ci/a), and tritium (0.2 Ci/a) in the total annual discharge of 240,000 curies. Within less than 2 months decay time, the dose from xenon-133 (half-life, 5.27 days) decreases by more than three orders of magnitude. Krypton-85 and tritium do not contribute significantly to the population dose in the vicinity of the plant because of their relatively low discharge quantity and weak beta radiation. The major concern regarding these two nuclides, having half-lives of 10.7 and 12.3 years, respectively, is the prospect for their long-term, worldwide environmental buildup. Detailed discussions regarding krypton-85 and tritium sources, their present worldwide inventory, future estimated accumulation and their interactions with biological systems can be found in references 14-20.

The halogens and particulates formed before and during the delay time in the gaseous waste system are removed by particulate and charcoal filters. Their total activity released into the atmosphere is generally a small fraction of the noble gas activity. However, they are mostly long-lived radionuclides which may be

Table 2. Isotopic composition of the noble gas discharges, Dresden Nuclear Power Station, 1970*

Radionuclide	Half-life	Unit 1				Unit 2				Total site	
		Percent of total release			Annual release ^a (Ci)	Percent of total release			Annual release ^a (Ci)	Total release (Ci)	Percent total
		Maximum	Minimum	Mean ^b		Maximum	Minimum	Mean ^b			
Xenon-135	9.2 hours	15.5	14.1	15	136,000	29.6	23.4	27	67,000	203,000	17.5
Krypton-87	1.3 hours	13.2	12.2	13	118,000	21	14.7	18	45,000	163,000	14.0
Xenon-133	5.3 days	8.5	6.8	7.4	67,000	22	14.5	18	45,000	112,000	9.8
Krypton-88	2.8 hours	20.3	9.3	15	136,000	19.1	13.3	17	42,500	178,000	15.5
Krypton-85m	4.4 hours	4.5	3.9	4.1	37,000	10.3	7.9	9	22,500	59,500	5.2
Xenon-138	17 minutes	32.8	26.4	30	270,000	11.2	2.6	5.7	14,500	284,500	24.5
Xenon-135m	15 minutes	18.7	13.3	16	145,000	11.3	1.1	5.3	12,500	157,500	13.5

* Data taken from reference 22.

^b Mean value based on three analyses performed during August, November, and December 1970, on gaseous samples taken at the steam jet air ejector.

^c Annual release values based on total annual release and mean percent of total release.

^d Mean value for Unit 2 based on five analyses performed during August–December 1970 on gaseous samples taken at the steam jet air ejector.

deposited on and assimilated into vegetation or accumulated in drinking water sources. Thus, through a variety of pathways they may contribute to the radiation exposure of the population at large. In the PHS special study (9), iodine-131 was found to be the critical radionuclide in the halogen and particulate stack discharges. The maximum potential exposure from iodine-131, via the pasture-cow-milk pathway, was estimated to be 0.28 millirem per year (21).

Table 2 provides a summary of the isotopic composition of the radioactive noble gases released from the Dresden Station and the contribution of each of the Dresden units to the total site releases during 1970. The Dresden Unit 1 isotopic composition values are based on three samples taken from the steam jet air ejector before discharge via the stack. The mean percentage composition of the various radiogases could be considered to be representative of the noble gas releases from Unit 1 during normal power operation.

The noble gases from Unit 2 were sampled and analyzed on seven occasions. However, the percent isotopic composition for Unit 2 includes the results of only five of the samples. The first two analyses were not included since they were taken early during the power test program when the predominating radionuclides in the core were short-lived. For these two samples, the short-lived radiogases, xenon-138 and krypton-87, constituted more than 50 percent of the noble gas activity. The percentage composition of these nuclides decreased as the power test program progressed. The five samples collected during the latter part of the program are considered more representative of the noble gas discharge composition for 1970. However, since the core inventory and discharges of radioactive materials are a function of factors such as thermal output, power history, fuel residence time, etc. (23), the percent composition for Unit 2 can be expected to change in time and is not considered to be typical for normal power operation.

Table 3. Estimated stack release rates of particulate radionuclides and gaseous iodine-131, Dresden Unit 1, 1970

Radionuclide	Half-life	Number of analyses	Release rates ^a (pCi/s)			Percent of release rate ^b	Annual releases ^c (Ci)
			Maximum	Minimum	Mean		
Cobalt-58	71.3 days	15	140	<8	26	1.1	0.036
Cobalt-60	5.26 years	16	95	2.5	25	1.0	.033
Strontium-89	52.7 days	15	2,300	220	970	40	1.3
Strontium-90	27.7 years	15	25	2	5	.2	.007
Cesium-137	30 years	16	55	13	35	1.4	.046
Barium-140	12.8 days	17	710	70	430	18	.6
Iodine-131	8.05 days	17	3,230	200	920	38	1.25

^a Release rates are taken from reference 9.

^b Percent of release rate is based on the total release rate for iodine and particulates and the mean release rate for each radionuclide (gaseous fission products are not included).

^c Annual releases based on the percent release rate and halogen and particulates total release from Unit 1 of 3.3 curies during 1970.

Table 3 provides a summary of the stack release rates for particulate radionuclides and gaseous iodine from Dresden Unit 1. The large variation in discharge rates for the various nuclides indicates that the release rates of the individual radionuclides and their amount relative to the total releases vary appreciably among samples. Nevertheless, the mean discharge rates provide a good indication of the relative contribution by each of the nuclides to the total activity of the halogen and particulate discharges. The 1970 estimated annual release of each of the nuclides is given in the last column. These releases are based on the percentage contribution of each nuclide to the total activity and on Unit 1 halogen and particulate annual discharges of 3.3 curies.

Table 4 summarizes Dresden Unit 1 annual noble and activation gas release rates for the past 11 years (12). Generally, the radioactive discharges increased with power history. A reduction in the total discharges during 1967 and 1968 was probably due to the removal and replacement of stainless-steel-clad fuel elements—a number of which were leaking—with new elements of Zircaloy cladding. During 1969 and 1970, the total activity released resumed the upward trend. However, an examination of the average release of radioactivity per megawatt electrical output shows a decrease in 1970 to the 1964-66 levels. This suggests that Unit 1 noble and activation gas discharges leveled off during this period.

A summary of the 1970 annual releases of radioactive gaseous effluents from the Dresden Station and the percentages of these releases relative to the permissible limits for each of the units, is provided in table 5 (25). The Dresden Units 1 and 2 percentages are based upon the technical specification limits of each unit as expressed in equation (1) and, as expressed in a similar formula, for the halogen and particulate effluents. The discharge of gaseous effluents as percentage of the site limit is the sum of the individual percentages for each of the units. The noble and activation gas releases during 1970 were 6.3 percent of the site limit.

For the noble and activation gas emissions, the site limit corresponds to an estimated maximum annual exposure of 500 millirems of external whole body dose at the site boundary or at a point of maximum potential ground level exposure offsite. Based on the 1970 noble and activation gaseous releases, the maximum potential whole body annual dose to an individual offsite was approximately 32 millirems.

Stack release limits for halogens and particulates include a reduction factor of 700 applied to the 10CFR20 (26) air concentration limits to allow for the potential environmental transfer and concentration of the radionuclides in milk. Thus the direct radiation from these nuclides and their contribution to the external whole body dose are negligible compared to the noble and activation gases.

Table 4. Annual noble and activation gas releases, Dresden Unit 1, 1960-1970

Year	Annual release ^a (Ci)	Average release rate		Gross generation (MW(e)h) ^c	Average release (Ci/MW(e)h)
		Annual (Ci/s)	Percent of limit ^b		
1960	3,200	0.0001	0.02	275,610	0.012
1961	46,490	.0002	.04	555,141	.012
1962	64,000	.0002	.36	1,249,602	.051
1963	72,000	.0023	.41	989,721	.074
1964	520,000	.017	3.0	1,037,511	.52
1965	610,000	.020	3.5	1,018,344	.61
1966	740,000	.024	4.3	1,474,832	.50
1967	260,000	.0083	1.5	853,567	.31
1968	240,000	.0076	1.4	966,792	.25
1969	860,000	.028	4.8	873,285	.98
1970	910,000	.029	5.2	1,428,826	.64
Average	390,000	0.013	2.2	974,840	0.36

^a Taken from reference 12 except as noted.

^b Percent of limit based on the release limit of 0.56 (Ci/s) applicable for Unit 1.

^c Data taken from reference 24.

^d Based on annual release rates taken from exhibit 2 of testimony by Robert Pavlick of the Commonwealth Edison Company, submitted at the Illinois Pollution Control Board hearings, December 8, 1970.

Table 5. Annual releases of radioactivity in the gaseous effluents, Dresden Nuclear Power Station, 1970

Type of release by unit	Annual release ^a (Ci)	Release rate (Ci/s)	Annual limit ^a (Ci)	Release rate limit (Ci/s)	Percent of limit ^a
Noble and activation gases:					
Unit 1.....	9.1×10^3	0.03	1.8×10^7	0.56	5.2
Unit 2.....	2.5×10^3	.008	2.2×10^7	.7	1.1
Total.....	1.16×10^4				6.3
Halogen and particulates:					
Unit 1.....	3.3	1.06×10^{-7}	75	2.4×10^{-6}	4.3
Unit 2.....	1.6	$.51 \times 10^{-7}$	110	3.5×10^{-6}	1.4
Total.....	4.9				5.7

^a Values taken from reference #5.

Radioactive liquid waste system

The Dresden Unit 1 liquid waste system and discharge canal are independent of the waste system and discharge canal shared by Units 2 and 3. The condenser coolant water used by the Dresden plants for dissipating excess heat and for initial dilution of radioactive waste is drawn from the Kankakee and Des Plaines Rivers and discharged into the Illinois River. In order to preclude any detrimental thermal effect in the portion of the Illinois River receiving the outflow of Units 2 and 3 coolant water, a cooling lake was constructed southeast of the Dresden site, below the Midwest Fuel Recovery Plant.³ Units 2 and 3 condenser coolant water will be diverted into the lake in order to dissipate excess heat by evaporation prior to discharge into the Illinois River.

The radioactive liquid waste systems of the Dresden plants include capabilities for holdup, filtration, evaporation, and demineralization. Liquid wastes are handled on a batch basis and treated according to their conductivity and radioactivity levels. Low level radioactive waste is usually filtered, while intermediate and high-level waste undergoes additional treatment by evaporation or demineralization. Processed liquid waste is either reused by the plant or discharged into the condenser coolant water. The rate of discharge into the coolant water canal is based on the radioactive concentration of the batch sample and on the water dilution flow rate at the discharge canal. When only

³ Operation of the cooling lake began in the fall of 1971.

gross beta analysis is performed, the technical specification requires that the gross beta activity in the discharge canal above background shall not exceed the average annual concentration of 1×10^{-7} $\mu\text{Ci}/\text{ml}$ (100 pCi/liter). For an unidentified mixture of liquid waste, all activity present is assumed to be due to the most restrictive isotope potentially present in the waste. The unidentified mixture limit is generally at least two orders of magnitude more restrictive than the limit otherwise applicable in the case of known isotopic composition.

The annual average condenser coolant water flow rate of Unit 1 is approximately 160,000 gallons per minute and the corresponding flow rate of Units 2 and 3 coolant water is approximately 940,000 gallons per minute. This water provides the initial dilution needed to maintain the radioactivity concentration in the discharge canal within the technical specification limits. A more detailed discussion of the sources of radioactive liquid wastes in nuclear power plants, the liquid waste systems, and treatment practices for the various categories of wastes can be found in references 7,8, and 27.

Radioactive liquid waste

The radioactive liquid waste effluents generally contain many of the same radionuclides found in the particulates and halogens of the gaseous effluents. These nuclides, as mentioned earlier, are neutron activation products and decay products of the short-lived radioactive noble gases. As a result of storage and proc-

Table 6. Estimated radionuclide concentrations in undiluted liquid waste (soluble portion only) exclusive of tritium, Dresden Unit 1, 1970

Radionuclides	Half-life	Radionuclide concentration ^a (pCi/ml)			Percent of total mean concentration	Annual discharges ^b (Ci)	Percent of concentration limits ^c
		Maximum	Minimum	Mean			
Iodine-131	8.05 days	46	6	22	3.1	0.25	73
Strontium-90	27.7 years	30	8	15	2.1	.17	50
Strontium-89	52.7 days	220	24	117	16.7	1.35	39
Cesium-137	30 years	150	35	106	15.1	1.25	5.3
Cesium-134	2.05 years	80	7	40	5.7	.47	4.5
Cobalt-60	5.26 years	500	1	129	18.3	1.50	2.6
Cobalt-58	71.3 days	880	3	226	32.3	2.64	2.3
Barium-140	12.8 days	65	22	40	5.7	.48	1.3
Cerium-144	284 days	—	—	48	1.1	.09	.8

^a Data taken from reference 9, based on five samples collected over a 10-month period during 1967-1968.

^b Based on the percent of total mean concentrations for each radionuclide and total radioactive liquid waste discharge from Unit 1 of 8.2 curies for 1970.

^c Based on the mean concentration and the concentration limit in water as specified in 10CFR20 (26).

^d Result of only one measurement.

essing time, most of the short-lived nuclides in the liquid waste decay before release. Consequently, the radionuclides released are mostly those with long half-lives. The percentage contribution of individual radionuclides to the total activity of the liquid effluents is considerably different from the corresponding values in the gaseous effluents. The less volatile and more soluble nuclides contribute a greater percentage of the liquid-waste activity. The insoluble radionuclides tend to be deposited, absorbed and accumulated downstream from the plant along the river bottom. The soluble nuclides, however, are easily transported and incorporated into the metabolic processes of biological systems and, thus, are much more likely to lead to population exposure.

Table 6 lists the major radionuclides found in a typical batch of liquid waste discharges with the average and range of the soluble

nuclide concentrations. As was the case with the gaseous effluents, the wide ranges of concentrations for the individual nuclides in the liquid effluents indicate that the release rates, as well as the activity of the individual nuclides relative to the total releases, vary appreciably among samples. Thus, the mean discharge rate values and the estimated annual discharges for 1970 should be construed only as indicators of the order of magnitude and relative contribution of the individual radionuclides to the total liquid waste activity.

The relative importance of each of the nuclides from the standpoint of population exposure, based on the mean concentration as a percentage of the concentration limit (CL) (26) is given in the last column of table 6. The critical radionuclide in the liquid waste is found to be iodine-131.

The average tritium concentration for the

Table 7. Annual releases of radioactivity in liquid effluents, Dresden Unit 1, 1960-1970^a

Year	Gross beta-gamma ^b (Ci)	Average release rate		Gross generation ^c (MW(e)h)	Average release rate (μ Ci/MW (e)h)
		Annual (μ Ci/ml) ^c (10 ⁻⁶)	Percent of limit ^d		
1960	0.77	0.23	2.3	275,610	2.7
1961	2.1	.63	6.3	555,141	3.8
1962	2.6	.79	7.9	1,249,602	2.1
1963	2.8	.84	8.4	989,721	2.8
1964	3.8	1.2	12	1,037,511	3.7
1965	8.7	2.6	26	1,018,344	8.5
1966	11.5	3.5	35	1,474,832	7.8
1967	4.3	1.3	13	853,567	5.1
1968	6.1	1.9	19	966,792	6.3
1969	9.5	2.9	29	873,285	11
1970	8.2	2.5	25	1,428,826	5.7
Average	5.5	1.7	17	974,840	5.4

^a Exclusive of tritium.

^b Data taken from reference 12.

^c Annual average release rate calculation based on the total annual discharge and on the average condenser water dilution flow rate of 160,000 gallons per minute.

^d Percent of limit based on the limit of 1×10^{-7} μ Ci/ml for unidentified radionuclides in liquid wastes.

^e Data taken from reference 24.

liquid samples mentioned above was approximately 850 pCi/ml, which is more than the total activity of all the halogen and particulate nuclides combined. However, when this value is considered relative to the CL of tritium, it is found to be less than 1 percent of the limit.

Table 7 summarizes the annual releases of radioactivity (excluding tritium) from the liquid effluents of Dresden Unit 1 for the past 11 years. Like the trend of the gaseous discharges, the activity of the liquid discharges showed a tendency toward leveling off at the 1970 discharge level. This trend is clearly indicated by the average release rate per unit electrical energy (last column). The 1970 value of 5.7 $\mu\text{Ci}/\text{MW}(\text{e})\text{h}$ is close to the average value of the previous years.

The average release rate of radioactivity from Unit 1, via the liquid waste, in the past 11 years was 16.7 percent of the unidentified mixture limit. As mentioned earlier, the percentage for a mixture of known isotopic composition is generally about two orders of magnitude less restrictive. Thus, the above percentage represents considerable overestimation.

Table 8 summarizes the 1970 discharges via the liquid effluents from Units 1 and 2 (25). The gross beta-gamma (exclusive of tritium) station discharge was 18 percent of the unidentified mixture limit. It is based on the total station discharge and total dilution water. The average annual tritium concentration at the coolant water discharge canals was a small percentage of the $3 \times 10^{-3} \mu\text{Ci}/\text{ml}$ concentration limit in water.

Dresden Nuclear Power Station environmental monitoring program

The Dresden environmental monitoring program has been in effect since 1958. With the anticipated power operation of the Dresden Units 2 and 3 and the Midwest Fuel Recovery Plant (MFRP), the scope of the surveillance program was subsequently broadened in a joint program by the General Electric Company, operator of the MFRP, and the Commonwealth Edison Company, operator of the Dresden Station. The expanded program was directed toward obtaining more extensive measurements of meteorological, radiological, and thermal parameters in order to minimize any future effects of the plants operation on the local environment. The findings of this program also increased the data base from which future evaluation of the station's impact on the local environment could be made with greater certainty. A summary of the program elements of the joint General Electric and Commonwealth Edison environmental monitoring program is provided in table 9 (28). The results of the monitoring program for 1970 are summarized and discussed below.

Radioactivity in air

Airborne radioactivity was monitored at 18 locations in and around the Dresden Station. Radioactive particulates were accumulated continuously on filter papers mounted on air samplers. The filters were collected weekly and analyzed for gross alpha and gross beta radio-

Table 8. Annual releases of radioactivity in the liquid effluents, Dresden Nuclear Power Station, 1970

Type of releases by unit	Total released (Ci)	Dilution water (ml)	Release rate ($\mu\text{Ci}/\text{ml}$)	Release rate limit ^a ($\mu\text{Ci}/\text{ml}$)	Percent of limit
Gross beta-gamma (exclusive of tritium):					
Unit 1	8.2	3.3×10^{14}	2.5×10^{-8}	1×10^{-7}	25
Unit 2	12.8	8.6×10^{14}	1.5×10^{-8}	1×10^{-7}	15
Summary	21.0	11.9×10^{14}	1.8×10^{-8}	1×10^{-7}	18
Annual tritium discharges:					
Unit 1	5	3.3×10^{14}	1.5×10^{-8}	3×10^{-3}	0.0005
Unit 2	31	8.6×10^{14}	3.6×10^{-8}	3×10^{-3}	.0012
Summary	36	11.9×10^{14}	3.0×10^{-8}	3×10^{-3}	0.001

^a Based on concentration limit as specified in 10CFR20 (26).

^b Based on an average water dilution flow rate in Unit 1 discharge canal of 160,000 gallons per minute.

^c Based on an average water dilution flow rate in Units 2 & 3 discharge canal of 430,000 gallons per minute.

^d Based on the total discharges from the station and on the sum of the dilution water of Unit 1 and Units 2 & 3 discharge canals.

Table 9. Dresden Nuclear Power Station environmental monitoring program^a

Sample type	Number of sites	Frequency of collection	Type of analysis	Minimum detectable levels (MDL) and units ^b
Airborne particulates.....	17	Monthly.....	Gross alpha	0.001 pCi/m ³
Airborne iodine-131.....	17	Weekly.....	Gross beta	.001 pCi/m ³
Ion-chambers.....	17	Weekly.....	Iodine-131	.03 pCi/m ³
TLD.....	17	Quarterly.....	Gross gamma	.6 mrem/week
			Gross gamma ^c	.3 mrem/week
Well water.....	1	Monthly.....	Gross alpha	2 pCi/liter
	6		Gross beta	2 pCi/liter
	10	Quarterly.....	Gross alpha	2 pCi/liter
			Gross beta	2 pCi/liter
			Tritium	1,000 pCi/liter
Surface water.....	3	Weekly.....	Gross beta	2 pCi/liter
	1	Quarterly.....	Gross alpha	2 pCi/liter
			Gross beta	2 pCi/liter
	5		Tritium	1,000 pCi/liter
	4	2 to 4 annually.....	Strontium-89	.5 pCi/liter
			Strontium-90	.5 pCi/liter
	1	Semiannually.....	Gross beta	2 pCi/liter
	3		Gamma scan	(^d)
			Gross beta	2 pCi/liter
Precipitation and deposition.....	2	Monthly.....	Gross alpha	20 pCi/m ²
	4		Gross beta	20 pCi/m ²
	4		Tritium	1,000 pCi/liter
Milk.....	2	Weekly (April-September).....	Iodine-131	10 pCi/liter
	2	Monthly.....	Strontium-89	1 pCi/liter
			Strontium-90	1 pCi/liter
			Cesium-137	10 pCi/liter
			Barium-140	10 pCi/liter
			Iodine-131	10 pCi/liter
Fish.....	3	2 to 4 annually.....	Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Gamma scan	(^d)
Foodstuff.....	3	Harvest time.....	Gross beta.....	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Cesium-137	10 pCi/kg
Grass.....	2	Monthly (April-September).....	Gross beta	20 pCi/kg
	2		Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Cesium-137	10 pCi/kg
			Iodine-131	10 pCi/kg
Vegetation.....	18	Annually ^e	Gross alpha	20 pCi/kg
			Gross beta	20 pCi/kg
	3		Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
Cattle feed.....	2	October and January.....	Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Cesium-137	10 pCi/kg
Aquatic plants.....	2	Semiannually.....	Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Gamma scan	(^d)
Slime.....	4	Semiannually.....	Gross beta	20 pCi/kg
			Gamma scan	(^d)
Soil.....	2	Annually.....	Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
			Cesium-137	10 pCi/kg
			Gamma scan	(^d)
	2	Quarterly.....	Gross alpha	20 pCi/kg
			Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
Bottom sediment.....	4	Semiannually.....	Gross beta	20 pCi/kg
			Strontium-89	5 pCi/kg
			Strontium-90	5 pCi/kg
	3		Gamma scan	(^d)

^a Taken from reference 28.^b MDL, minimum detectable level. Since the MDL depends on factors such as analytical procedures, sample size, counting instrumentation, etc., the values given are not theoretical levels of detection but rather approximate values of sensitivity which indicate a practical minimum detection level.^c Beta radiation is not detected, because of the encapsulation of the TLD's.^d MDL is a function of the complexity of the spectrum, sample size, geometry used and instrumentation.^e At end of growing season.

Table 10. Gross beta radioactivity in airborne particulates, Dresden Nuclear Power Station, 1970^a

Sampling locations	Distance from station (miles)	Number of samples ^b	Radioactivity concentration (pCi/m ³)		
			Maximum	Minimum	Mean
Onsite:					
#1.....	NW	52	1.00	0.04	0.19
#2.....	NE	48	.57	.03	.18
#3.....	S	51	.53	.04	.16
Offsite:					
Bennet.....	1 NE	48	.47	.03	.15
Lorenzo.....	2.1 SSE	52	.47	.04	.14
Clay Product.....	2.5 S	52	.55	.03	.16
McCabe.....	2.9 WSW	49	.62	.06	.17
Channanon.....	4.2 NE	49	.50	.04	.16
Minooka.....	4.4 NNE	52	.47	.03	.16
Coal City.....	8.0 S	52	.49	.03	.15
Morris.....	8.0 SW	52	.51	.03	.16
Elwood.....	8.2 E	52	.48	.03	.16
Wilmington.....	8.6 SE	48	.47	.03	.14
Libon.....	12.2 NW	51	.57	.04	.16
Joliet.....	12.7 NE	52	.50	.03	.15
Plainfield.....	15.7 NNE	45	.54	.02	.16
Summary: Onsite.....		151	1.00	0.03	0.18
Offsite.....		654	0.62	0.02	0.16

^a Data taken from reference 29.

^b Sample collection frequency on weekly basis.

^c Radiochemical analysis revealed 0.98 pCi/m³ of zirconium-95 and traces of radioiodine.

Table 11. Summary of the mean gross beta radioactivity in airborne particulates, 1970

Station	Number of samples	Radioactivity concentration (pCi/m ³)				Annual summary
		Jan-Mar	Apr-June	July-Sept	Oct-Dec	
Dresden.....	805	0.09	0.28	0.20	0.06	0.16
Quad-Cities.....	154	.08	.24	.19	.05	.15
Zion.....	129	NA	NA	.18	.07	.13

NA, no analysis.

activity. None of them showed gross alpha radioactivity from long-lived nuclides above the minimum detectable level. A summary of the gross beta radioactivity is given in table 10.

Comparison between the mean gross beta radioactivity in airborne particulates around the Quad-Cities and the Zion Stations with that of the Dresden Station (table 11) indicates that the Dresden particulate discharges for 1970 were hardly detectable. The quarterly fluctuations in the particulate gross beta activity at the three stations showed seasonally dependent variations. These seasonal fluctuations are typical of fallout of stratospheric origin from previous nuclear tests.

One of the more important groups of radionuclides present in the gaseous effluents are the isotopes of iodine and particularly iodine-131 (half life, 8.05 days) which may lead to a

population exposure via the pasture-cow-milk pathway. The presence of iodine-131 in air was monitored weekly at eight locations within 4 to 16 miles from the Dresden Site. Radioiodine in air is monitored by inserting charcoal cartridges behind the filters of the particulate samplers. Most of the measurements for iodine were below the minimum detectable level. However, during the second and fourth quarters slight increases in the iodine concentration were observed in many of the sampling stations. The annual mean concentration of iodine for all the sampling locations was 0.01 pCi/m³. This value is well within the limit of 0.14 pCi/m³ for iodine.⁴

⁴ The limit includes a reduction factor of 700 to the concentration limit of radioactive iodine in air of 1×10^{-10} μ Ci/cc (100 pCi/m³) in order to account for the potential environmental transfer and concentration of radioiodine in the milk-exposure pathway.

External exposures resulting from radioisotopes of the noble gases, krypton and xenon, were monitored at 18 locations within a 16-mile radius from the station. Monthly measurements were made with thermoluminescent dosimeters (TLD) and film badges while weekly measurements were made with an ion-chamber. Due to their insensitivity at low exposures, all film badge exposures were below the minimum detectable level of approximately 45 millirems. Table 12 provides a comparison between the mean annual external exposure in the vicinity of the Dresden Station to the corresponding exposures near the Quad-Cities and the Zion Stations. The annual exposure values suggest that the radioactive gaseous effluents

released from the Dresden Station resulted in an increase of the external background radiation near the site.

The ion-chamber weekly measurements and the net increase in annual external gamma exposures are summarized in table 13. The average net increase in external exposure 2 to 16 miles from the station is indicated to have been approximately 7 millirems per year.⁵ A background external exposure level of 99 millirems per year (1.9 mrem/week) was subtracted from the annual gross ion-chamber exposures,

⁵ Dr. John C. Golden, staff radioecologist, Commonwealth Edison Company (in a personal communication), pointed out that the 10 mR ion chambers used by the Commonwealth Edison Company measure only gross changes in ambient gamma radiation levels. These measurements are affected by temperature, atmospheric pressure, humidity, calibration method, charge leakage, and readout error. Dr. Golden also questioned the accuracy of the TLD values (table 13). He pointed out that the TLD's are affected by the inherent radiation from the encapsulation housing and the dose accumulated during the period between the critical annealing and placement in the environs as well as the interval between the removal from the housing and readout. In light of all these variables, any net value derived from the ion-chamber and TLD measurements is of questionable reliability and validity at the low levels of exposure in the environs discussed herein.

Table 12. Summary of the mean ion-chamber measurements, onsite and offsite, 1970

Station	Number of readings	Gross external exposure	
		(mrem/week)	(mrem/a)
Dresden.....	774	2.1	111
Quad-Cities.....	732	1.8	90
Zion.....	147	1.8	94

Table 13. Summary of external gamma radiation, Dresden Nuclear Power Station, 1970^a

Reading location	Distance from site (miles)	Ion-chamber measurements					Net exposure	
		Number of readings ^b	Maximum (mrem/week)	Minimum (mrem/week)	Mean (mrem/week)	Annual ^c (mrem)	Ion-chamber ^d (mrem/a)	TLD ^e (mrem/a)
Onsite:								
#1.....	NW	44	3.5	1.5	2.2	116	33	37
#2.....	NE	43	5.5	1.6	2.9	152	69	77
#3.....	S	43	3.0	1.5	2.0	107	24	33
Perimeter:								
Bennet.....	1 NE	42	4.0	1.5	2.1	109	26	32
Breen.....		43	3.0	1.8	2.2	115	32	27
Hansel.....	1.5 NNW	43	2.6	1.8	2.1	110	27	29
Offsite:								
Lorenzo.....	2.1 SSE	43	2.7	1.5	2.1	108	9	2
Clay Product.....	2.5 S	43	3.0	1.5	2.1	108	9	16
McCabe.....	2.9 WSW	43	3.0	1.5	2.0	105	6	11
Channanon.....	4.2 NE	42	4.5	1.0	2.0	105	6	9
Minooka.....	4.4 NNE	42	2.5	1.5	2.0	104	5	5
Coal City.....	8.0 S	44	2.5	1.5	2.0	106	7	3
Morris.....	8.0 SW	43	3.0	1.4	2.0	103	4	5
Elwood.....	8.2 E	44	3.0	1.5	2.2	113	14	7
Wilmingon.....	8.6 SE	42	2.5	1.5	2.0	104	5	8
Lisbon.....	12.3 NW	43	2.8	1.5	2.0	104	5	4
Joliet.....	12.7 NE	44	2.5	1.5	2.1	108	9	0
Plainfield.....	15.7 NNE	43	3.0	1.5	2.0	102	3	5
Summary: Onsite.....		130	5.5	1.5	2.4	125	42	49
Perimeter.....		128	4.0	1.5	2.1	111	28	29
Offsite.....		516	3.0	1.0	2.0	106	7	6

^a Data taken from reference 29.

^b Reading frequency on weekly basis.

^c Annual external radiation at each location is extrapolated for 52 weeks based on the number of readings at that location.

^d Net ion-chamber exposure is based on the annual ion-chamber exposure minus background; background external exposure onsite and at the perimeter locations (along the Illinois River shores) is taken as 83 millirems per year. The background external exposure offsite is taken as 99 millirems per year (1.9 mrem/week) as measured during the 4th quarter of 1969 when Dresden station was not operating.

^e Net TLD exposure measurements are sum of the quarterly TLD readings. Net readings onsite and at the perimeter locations are adjusted to account for the differences in background external radiation near the river and at locations offsite (see footnote d).

offsite. This value is based on measurements made during the last quarter of 1969 when the Dresden Station was not operating.

An examination of the quarterly background ion-chamber measurements around the Quad-Cities and the Zion Stations indicates that the external exposures corresponding to the fourth quarter were approximately 27 percent of the annual exposures. Thus, the background external exposure of 99 millirems per year in the vicinity of the Dresden Station may be an overestimation, and consequently, the net exposure offsite may represent an underestimation of the increase in external exposure resulting from the station discharges.

The average net increases in external exposures onsite and at the perimeter locations along the Illinois River shores were approximately 46 and 29 millirems per year, respectively. These values are based on a background external exposure onsite and along the river of approximately 83 millirems per year. This background value is in accord with the findings around the Quad-Cities and the Zion Stations in which the background exposures onsite at both stations were determined to be approximately 83 millirems per year; whereas the exposures offsite were found to be approximately 98 millirems per year (tables 20 and 23).

Radioactivity in water

The environmental monitoring program of the Dresden Station included sampling of surface water, well water, precipitation and deposition. Surface water samples were collected weekly from the intake and discharge canals as well as from upstream and downstream locations. The weekly samples were analyzed for gross beta radioactivity, while quarterly and semiannual composites of the samples were analyzed for tritium. The semiannual composites were also analyzed for strontium-89 and strontium-90 concentrations. The tritium and strontium-89 measurements were at or below the minimum detectable levels, while the strontium-90 concentration was comparable to the background level found in surface water around the Quad-Cities Station.

Table 14 summarizes the gross beta analy-

sis results for the surface water samples. The mean gross beta activity of 5.0 pCi/liter at the intake canal indicates the radioactivity from fallout and natural sources. Samples from the discharge canals of Units 1 and 2 contained additional radioactivity above the level found in the intake canal. This additional activity gives a measure of the contribution from the units' radioactive wastewater. The dilution water of Unit 2 decreased the average gross beta concentration of the surface water in the discharge canal to levels well within the range of concentrations in the upstream surface water. Considering that gross beta activity in surface water varies appreciably between influent and effluent water for normal water flow in the absence of discharges, the added activity detected at Unit 2 discharge canal was negligible. Unit 1 discharge canal mean gross beta radioactivity, however, was significantly higher than the activity in the intake water and upstream. Still, it was only about 6 percent of the annual gross beta radioactivity limit of 100 pCi/liter for an unidentified mixture of radionuclides in liquid waste.

Table 14. Summary of gross beta radioactivity in surface water, Dresden Nuclear Power Station, 1970*

Sampling locations	Distance from site	Number of samples	Radioactivity concentration (pCi/liter)		
			Maximum	Minimum	Mean
Intake canal.....	Onsite	52	28.8	ND	5.0
Discharge canal:					
Unit 1.....	Onsite	52	26.0	ND	11.1
Unit 2.....	Onsite	48	14.2	ND	5.7
Illinois River at Morris.....	10 miles downstream	24	10.4	ND	5.7
Railroad bridge..	1 mile downstream	48	22.1	2.99	7.7
Gooselake.....	1 mile upstream	52	17.3	ND	6.2
Summary.....		276	28.8	ND	6.9

* Data taken from reference 29.

ND, nondetectable. For minimum detectable levels see table 9.

It is worth noting that the 1970 calculated gross beta concentrations at Units 1 and 2 discharge canals were 25 and 15 percent, respectively, of the unidentified mixture limit (table 8). On the other hand, the measured gross beta concentrations at the discharge canals of Units 1 and 2, as mentioned above, were considerably smaller percentages of the unidentified mixture limit. This suggests that the surface water

**Table 15. Summary of gross beta radioactivity in well water
Dresden Nuclear Power Station, 1970***

Sampling location	Distance from station (miles)	Number of samples	Radioactivity concentration (pCi/liter)		
			Maximum	Minimum	Mean
Well#1.....	Onsite	4	18.2	14.9	16.7
Well#2.....	Onsite	4	21.8	10.7	13.9
Drinking fountain.....	Onsite	3	16.1	13.8	15.2
Gate house.....	Onsite	2	18.1	15.4	16.8
Lock and Dam.....	0.5 NW	13	15.6	8.89	12.3
Bennet.....	1 NE	4	15.9	6.24	9.85
Hansel.....	.75 NW	4	5.40	2.78	4.92
Olson.....	.5 SE	4	6.77	2.18	4.0
Joliet Yacht Club.....	1.7 NE	4	15.3	6.53	9.79
Thorsen.....	.5 S	4	9.07	ND	4.23
Dirker.....	2.1 W	4	14.3	6.01	11.8
Summary.....		50	21.8	ND	10.9

* Data taken from reference 29.
ND, nondetectable. For minimum detectable levels see table 9.

samples may not have been representative of the water in the discharge canals. A portion of the insoluble radionuclides in the liquid wastes may have been deposited immediately upon release thus resulting in a decrease in the radionuclide concentration at the point where the surface water samples were collected.⁶ The surface water gross beta activity downstream, 1 mile from the Dresden Station, shows the contribution from Units 1 and 2 discharges. The mean activity of 7.7 pCi/liter was well within the river's normal background variations.

Radioactivity in precipitation and deposition was determined from samples collected weekly from two farms and from monthly samples collected onsite and 1 mile offsite. The samples were analyzed for gross beta radioactivity. The weekly and monthly gross beta measurements showed comparable concentrations. However, gross beta activity of samples at each of the stations showed wide variations with no apparent correlation to seasonal changes. Similar wide variations were observed at the Quad-Cities and Zion Stations. In view of the fact that airborne particulates monitoring around the Dresden Station did not show any abnormally high particulates activity, the elevated activity observed in some of the precipi-

tation and deposition samples very likely reflected normal background variations.

In order to ensure detection of any ground water contamination, well-water samples were collected quarterly onsite and at seven locations offsite. All the samples were analyzed for gross beta radioactivity. Eight samples from two of the offsite locations were also analyzed for gross alpha and tritium concentrations. No tritium was detected in any of the samples. The gross alpha concentrations were within normal background range with a mean concentration of approximately 1 pCi/liter. The mean gross beta concentration of all the samples was 10.9 pCi/liter while the mean activity for the samples collected onsite was 15.3 pCi/liter (table 15). These values are relatively high in comparison to the activity found in samples collected around the Quad-Cities and the Zion Stations (table 16). In the absence of specific radionuclide analyses, the origin of the gross beta activity found in the well water samples cannot be ascertained. Past studies, however, indicated that many wells in Illinois have rela-

Table 16. Summary of the mean radioactivity in well water, 1970

Station	Number of samples	Radioactivity concentration (pCi/liter)	
		Gross alpha	Gross beta
Dresden.....	50	*1.0	10.9
Quad-Cities.....	36	.35	2.1
Zion.....	15	.5	1.3

* Only eight samples from two locations were analyzed for gross alpha.

⁶ Dr. John C. Golden, staff radioecologist, Commonwealth Edison Company, suggests (in a personal communication) the following additional possible explanations: (a) absorption of the soluble ions on the surface of the sediments in the discharge canals, (b) overestimation of the activity in the liquid waste, and (c) underestimation of the dilution water flow rate.

Table 17. Summary of mean radioactivity in milk, 1970

Station	Number of samples	Radioactivity concentration (pCi/liter)					Calcium (g/liter)	Strontium-90 (pCi/gCa)
		Gross beta ^a	⁹⁰ Sr	⁹⁰ Sr	¹³⁷ Cs	¹³¹ I		
Dresden	24	627	ND	5.0	5.1	ND	1.00	5.0
Quad-Cities	24	638	ND	6.8	5.3	ND	1.11	6.1
Zion	12	NA	ND	7.3	7.4	ND	1.08	6.8

^a Based on calibration with a strontium-yttrium standard. These figures are considered to be low because of reduced counter efficiency due to high solids absorption.

ND, nondetectable.

NA, no analysis.

tively high gross alpha and gross beta concentrations resulting from radionuclides of natural sources. Nonetheless, to place the values in perspective, the mean well water gross beta activity of 10.9 pCi/liter, assuming strontium-90 is absent, is approximately 1 percent of the applicable Public Health Service drinking water standard of 1,000 pCi/liter (30).

Radioactivity in foods

The environmental monitoring program of the Dresden Station included analyses of major items along the food-chain pathways. Samples of milk, vegetables, fish, forage such as grass, and other assorted cattle feed, were collected and analyzed for gross beta and specific radionuclide concentrations.

The monitoring of the pasture-cattle-milk pathway is one of the most effective ways of determining the intake level of radioiodine, radiostrontium and radiocesium. Milk, being a major dietary item, is one of the best indicator media for measurements of environmental changes in the concentrations of these radionuclides as well as other fission products. Milk samples were collected weekly from two farms. A comparison between the mean concentrations of the radionuclides found in milk collected around the Dresden Station and the corresponding concentrations in samples collected around the Quad-Cities and Zion Stations (table 17) indicates that the radioactivity in the Dresden milk samples was of natural and fallout origin with no apparent contribution attributable to the Dresden Station discharges.

Grass samples were collected monthly during the grazing season while cattle feed was collected off-season from the two farms from

which the milk samples were taken. In addition, a special analysis was conducted on grass samples from five locations onsite and five off-site. Although the onsite samples generally showed higher concentrations of cesium-137 and strontium-90, their radionuclide content was within the levels found in the grass samples collected around the Quad-Cities and Zion Stations and thus reflected only background variations.

Fish samples were collected from the Kankakee and the Illinois Rivers and were analyzed for a variety of radionuclides. The results of the analyses indicated no significant difference between the samples collected upstream from the Kankakee River and downstream from the Dresden Pool, and Lock and Dam. The presence of radionuclides resulting from the possibility of selective intake and concentration in fish was monitored by gamma spectrometry. No unusually high concentration of any radionuclide was detected.

Radioactivity in other media

The radionuclides discharged in the liquid waste may accumulate in soil, slime or along the river bottom sediment which serve as integrator media for the aqueous radioactivity levels. Samples of slime and sediments were collected periodically from the inlet and discharge canals and from an upstream sampling location in the Kankakee River. Radioactivity measurements on the upstream and the inlet and discharge canals samples showed comparable levels. However, in a special analysis of the bottom sediments, the mean gross beta activity of samples collected downstream at the Dresden Pool, was approximately 14,000 pCi/

Table 18. Summary of environmental monitoring data, Dresden Nuclear Power Station, 1970^a

Sampling media and units	Number of samples ^b	Type of analysis	Radioactivity concentration		
			Maximum	Minimum	Mean
Airborne particulates (pCi/m ³)	188 (16)	Gross alpha	ND	ND	ND
	805 (16)	Gross beta	1.0	0.02	0.16
Airborne iodine-131 (pCi/m ³)	403 (8)	Iodine-131	.06	ND	.01
Ion-chamber (mrem/week)	774 (18)	Gross gamma	5.5	1.0	2.1
TLD (mrem/a)	72 (18)	Net gamma	77	ND	17
Well water (pCi/liter)	8 (2)	Gross alpha	3.3	ND	1.3
	50 (11)	Gross beta	22	ND	11
	8 (2)	Tritium	ND	ND	ND
Surface water (pCi/liter)	271 (6)	Gross beta	26	ND	6.9
	*10 (5)	Strontium-89	ND	ND	ND
		Strontium-90	3.5	.53	2.1
	*20 (5)	Tritium	ND	ND	ND
Precipitation (pCi/liter)	24 (2)	Gross alpha	3	ND	.8
	128 (4)	Gross beta	490	2.0	58
Deposition (pCi/m ² -week)	104 (2)	Gross beta	58,600	120	6,280
(pCi/m ² -month)	24 (2)	Gross alpha	330	ND	36
		Gross beta	18,200	80	2,500
Milk (pCi/liter)	*24 (2)	Gross beta ^d	1,000	200	630
		Strontium-89	ND	ND	ND
		Strontium-90	11	.71	5.0
		Cesium-137	9.1	2.2	5.1
		Strontium-90 ^e	12	.66	6.1
Fish ^f (pCi/kg)	52 (2)	Iodine-131	ND	ND	ND
	*31 (3)	Gross alpha	ND	ND	ND
		Gross beta	6.7	1.2	3.2
	5 (3)	Cobalt-60	ND	ND	ND
		Zinc-65	ND	ND	ND
		Strontium-90	1.0	ND	.35
		Cesium-137	.35	ND	.1
	31 (3)	Gamma scan ^h	ND	ND	ND
Vegetables ⁱ (pCi/kg)	39 (3)	Gross beta	56	5	23
Cattle feed ^k (pCi/kg)	16 (3)	Gross beta	11,000	1,200	4,300
		Strontium-89	ND	ND	ND
		Strontium-90	1,200	48	270
		Cesium-137	1,100	70	340
		Iodine-131	ND	ND	ND
Grass ^m (pCi/kg)	14 (2)	Strontium-89	ND	ND	ND
		Strontium-90	1,600	190	740
		Cesium-137	1,200	180	510
	* 10 (10)	Strontium-90	1,500	300	660
		Cesium-137	340	180	240
		Iodine-131	ND	ND	ND
Slime ⁿ (pCi/kg)	12 (3)	Gross beta	19,000	4,700	9,600
		Gamma scan ^p	ND	ND	ND
Soil ^q (pCi/kg)	3 (3)	Gross alpha	830	330	600
		Gross beta	6,600	1,600	4,000
		Strontium-89	ND	ND	ND
		Strontium-90	390	30	220
		Cesium-137	870	160	480
		Gamma scan ^p	ND	ND	ND
Sediments ^r (pCi/kg)	8 (3)	Gross beta	9,300	170	4,100
		Strontium-89	ND	ND	ND
		Strontium-90	270	11	91
		Gamma scan ^p	ND	ND	ND
	* 15 (3)	Gross beta	14,000	560	5,900
		Gamma scan ^r	ND	ND	ND
	3 (3)	Gross alpha	6,100	4,000	4,900
		Strontium-90	400	70	200
		Cesium-137	520	460	490
		Zinc-65	1,700	ND	ND
		Cobalt-60	2,000	ND	670

^a Data taken from reference 29.^b Number in parenthesis indicates number of sampling locations.^c Composite samples.^d Based on calibration with a strontium-yttrium standard. These figures are considered to be low because of reduced counter efficiency due to solids absorption.^e Reporting unit is pCi of strontium-90 per gram of calcium.^f Results reported per edible wet weight: wet/dry weight ~3.8 based on reported weight for two samples.^g Samples included: 22 carps, 7 bullheads, 1 perch, and 1 eel.^h Gamma scan for potassium-40, iron-59, ruthenium-106 and thorium plus daughters.ⁱ Analysis results based on wet weight: wet/dry weight ~1.1.^j Samples included tomatoes, cabbage, cucumbers, corn, squash, onions, melon and others.^k Analysis results based on dry weight: wet/dry weight ~1.6.^l Samples included ground grain, hay, silage, corn and soybeans.^m Analysis results based on dry weight: wet/dry weight ~3.2.ⁿ Special analyses: wet/dry weight ~3.9.^o Gamma scan for iron-59, cobalt-60, zirconium-95, ruthenium-106, cesium-137.^p Special analysis: samples collected from the Kankakee River, Dresden lock and dam, and Dresden pool.^q Gamma scan for potassium-40, iron-59, zirconium-95, ruthenium-106, and thorium plus daughter.^r ND, nondetectable. For minimum detectable levels see table 9.

kg of dry weight, whereas samples upstream showed activity of approximately 3,630 pCi/kg of dry weight. Isotopic analyses of three of the samples, one per sampling location, having the highest gross beta activity, detected the presence of zinc-65 in the downstream samples of reactor origin. The result of the special analysis suggests that the discharge canal coolant water transports and deposits at least some of the insoluble radionuclides along the bottom of the Illinois River at Dresden Pool. Since there are many factors affecting the radionuclide concentration measurements in sediments, i.e., sediment texture, water velocity, sampling location, sampling technique, etc. (31), it is difficult to determine from the reported data whether the accumulation of zinc-65 in Dresden Pool was significantly above background.

Table 18 provides a summary of the environmental monitoring data gathered during 1970 in the surveillance program of the Dresden Station (29).

Quad-Cities Nuclear Power Station

The Quad-Cities Nuclear Power Station is on the eastern shore of the Mississippi River in Rock Island County, Ill., about 140 miles west southwest of Chicago. The nearest population center is Clinton, Iowa (1960 population total, 35,700), located about 7 miles northeast of the site. Approximately 20 miles southwest of the station are the Quad-Cities: Davenport, Iowa, and Moline, East Moline and Rock Island, Ill. (1970 population total, 215,704).

The Quad-Cities Units 1 and 2 utilize two boiling water reactors, each designed to operate at a net electrical output of 809 megawatts. The units share the principal structures of the plant (i.e., reactor building, turbine building and radwaste building) and many other facilities among which are: a stack 310 feet high; a reactor building ventilation stack; a cooling water intake structure; a discharge canal structure and a radioactive liquid waste system (32). Neither unit was operational during 1970, thus no radioactive effluents were released to the Illinois environment during that period.

Quad-Cities Nuclear Power Station environmental monitoring program

In order to establish the background radiological conditions in the vicinity of the Quad-Cities Station and to evaluate the potential impact of thermal discharges on the Mississippi River biota and water quality, Commonwealth Edison Company conducted preoperational environmental studies beginning in 1968 and continuing through 1970. In these studies, special emphasis was placed on characterizing the aquatic biota of the Mississippi River and, in particular, of Pool 14 which will provide cooling water and dilution for the plant thermal and radioactive discharges. Samples of benthic organisms, phytoplankton, zooplankton, fish and macrophytes were collected, and their habitat and seasonal variations were studied (33). In addition, samples of water, air, foods and other miscellaneous media were analyzed for background radioactivity content. Table 19 summarizes the elements of the Quad-Cities environmental monitoring program (32,34). A brief description of the preoperational phase of this program, and a summary of the data gathered during 1970 follows.

Background environmental radioactivity

A variety of environmental media was collected and analyzed for gross radioactivity and radionuclide content. Ion-chamber gamma radiation measurements were made weekly and cumulative monthly external exposures were monitored with TLD and film badges at 16 locations around the Quad-Cities station. All of the film badge readings were below the minimum sensitivity. A summary of the ion-chamber and TLD measurements and the corresponding annual external exposures is provided in table 20. The mean radiation background for all the monitoring stations was 1.8 millirem per week which corresponds to an annual background radiation of approximately 90 millirems. This value is in good agreement with the TLD's mean annual cumulative reading of approximately 97 millirems.

It should be noted that the TLD and ion-chamber measurements onsite indicated a mean external background radiation of approximately 83 millirems per year whereas measurements

Table 19. Quad-Cities Nuclear Power Station environmental monitoring program^a

Sample type	Number of sites	Sampling frequency	Type of analysis	Minimum detectable levels (MDL) and units ^b
Airborne particulates.....	16	Weekly	Gross alpha Gross beta Gamma scan	0.001 pCi/m ³ .001 pCi/m ³
Airborne iodine-131.....	8	Weekly	Iodine-131	.03 pCi/m ³
Ion-chambers.....	16	Weekly	Gross gamma	.6 mrem/week
TLD.....	16	Quarterly	Gross gamma ^c	.3 mrem/week
Well water.....	2	Monthly	Gross alpha Gross beta	2 pCi/liter 2 pCi/liter
	1	Quarterly	Gross alpha Gross beta	2 pCi/liter 2 pCi/liter
Surface water.....	4	Weekly ^d	Gross alpha Gross beta	2 pCi/liter 2 pCi/liter
		Quarterly	Strontium-89 Strontium-90 Tritium	.5 pCi/liter .5 pCi/liter 1,000 pCi/liter
Precipitation and deposition.....	3	Monthly	Gross alpha Gross beta Gross alpha Gross beta	2 pCi/liter 2 pCi/liter 20 pCi/m ² 20 pCi/m ²
Milk.....	2	Monthly ^e	Iodine-131 Strontium-89 Strontium-90 Cesium-137	10 pCi/liter 1 pCi/liter 1 pCi/liter 10 pCi/liter
Fish.....	2	4 Annually	Gross alpha Gross beta Gamma scan Strontium-89 Strontium-90	12 pCi/kg 120 pCi/kg *(4) pCi/kg 15 pCi/kg 15 pCi/kg
Vegetables.....	4	3 Annually	Gross beta Strontium-89 Strontium-90 Cesium-137	20 pCi/kg 5 pCi/kg 5 pCi/kg 10 pCi/kg
Grass.....	2	Monthly (April-Sept)	Gross beta Strontium-89 Strontium-90 Cesium-137	20 pCi/kg 5 pCi/kg 5 pCi/kg 10 pCi/kg
Cattle feed.....	2	Monthly (Oct-Nov)	Gross beta Strontium-89 Strontium-90 Cesium-137	20 pCi/kg 5 pCi/kg 5 pCi/kg 10 pCi/kg
Vegetation.....	16	Annually	Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg (*) pCi/kg 5 pCi/kg 5 pCi/kg
Slime.....	16	Quarterly	Gross alpha Gross beta Gamma scan	20 pCi/kg 20 pCi/kg (*) pCi/kg
Soil.....	2	Annually	Gross beta Gamma scan Strontium-89 Strontium-90 Cesium-137	20 pCi/kg (*) pCi/kg 5 pCi/kg 5 pCi/kg 10 pCi/kg
Bottom sediment.....	4	Semiannually Annually	Gross alpha Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg 20 pCi/kg (*) pCi/kg 5 pCi/kg 5 pCi/kg
Special analysis ^b	Varies	Varies	Varies	Varies

^a Taken from references 32, 34.^b MDL, minimum detectable level. Since the MDL depends on factors such as analytical procedures, sample size, counting instrumentation, etc., the values given are not theoretical levels of detection but rather approximate values of sensitivity which indicate a practical minimum detection level.^c Beta radiation is not detected because of encapsulation of the TLD's.^d Composite samples.^e Iodine-131 analyses eliminated during winter months.^f pCi/kg or edible portion.^g MDL is a function of the complexity of the spectrum, sample size, geometry used and instrumentation.^h Analyses performed upon owner's request.

Table 20. Summary of external gamma radiation background, Quad-Cities Nuclear Power Station, 1970^a

Sampling location	Distance from station (miles)	Ion-chamber measurements					TLD annual ^d (mrem)
		Number of readings ^b	Maximum (mrem/week)	Minimum (mrem/week)	Mean (mrem/week)	Annual ^c (mrem)	
Onsite:							
#1	N	47	3.5	0.7	1.6	83	80
#2	E	47	2.1	.9	1.5	80	80
#3	S	46	2.5	.8	1.8	85	90
Offsite:							
Nitritin	1.7 NE	47	2.1	1.0	1.6	85	90
Hansons boat dock	1.8 NW	47	2.2	1.2	1.7	91	110
Saddle Club dairy	1.8 SSE	47	2.3	1.0	1.8	93	90
Princeton	2.5 SW	47	2.4	1.2	1.9	97	100
Low Moor	5.9 NW	47	2.5	1.0	1.7	89	100
Sikkema Farm	6.5 ENE	47	2.5	1.0	1.8	95	100
Port Byron	8 S	47	2.2	—	1.7	88	120
Clinton	9.3 NE	29	3.0	1.3	1.9	100	110
Hillsdale	10.1 SE	47	2.3	1.0	1.7	88	100
Utica Ridge road	11.3 W	47	2.1	1.2	1.7	88	90
Erie	12.3 ESE	47	2.8	1.1	1.8	94	110
Dewitt	13.5 NW	47	2.1	.6	1.7	86	90
Bettendorf	17 SW	46	2.7	1.1	1.9	100	90
Summary: Onsite		140	3.5	0.7	1.6	83	83
Offsite		592	3.0	0.6	1.8	92	101

^aData taken from reference 35.^bMeasurements taken on weekly basis.^cExtrapolated for 52 weeks based on number of readings at each location.^dValues given for annual cumulative TLD measurements.

offsite, within a radius of 17 miles, indicated a mean annual background radiation of approximately 96 millirems. These differences are likely attributable to the stations' proximity to an aquatic environment. Since the Quad-Cities site is along the Mississippi River shore, the contribution of terrestrial sources to the overall background radiation level is apparently lower onsite as compared to locations further inland.

Radioactivity levels in precipitation and deposition were determined on monthly samples. Gross beta measurements of samples collected at each of the sampling locations around the station showed comparable mean monthly values. However, as was the case for samples collected around the Dresden Station, measurements made within each location showed wide variations. For example, the gross beta concentration of precipitation, onsite, had a range of 7.4-300 pCi/m²-month.

The preoperational environmental monitoring program included measurements of the background radionuclide concentration along the food-chain pathways. Samples of fish, vegetables, and milk, as well as grass and miscellaneous other vegetations were collected and analyzed for gross beta radioactivity and for strontium-89, strontium-90, and cesium-137 of fallout origin.

Fish samples, collected from the local market at Davenport, included a representative sample of the Mississippi River sport and commercial fish. The gross alpha, gross beta, specific radionuclides analyses and gamma spectrometry, all indicated normal background concentrations with no unusually high levels of any radionuclide due to selective metabolic concentration.

A comparison between the vegetable analysis results of the Quad-Cities and the Zion Stations shows wide differences in the radioactivity levels at the two stations. Since the results represent background radioactivity levels, it is unlikely that differences as large as three orders of magnitude are attributed to natural background variations in the radionuclide content of the soil or dry deposition at the two sites. Thus, it appears that these reported data are unreliable.⁷

In order to determine the extent to which radionuclides from the Quad-Cities Station liquid discharges will accumulate along the

⁷ In a personal communication, Dr. John C. Golden, staff radioecologist, Commonwealth Edison Co. confirmed that the vegetable analysis results for 1970 from Dresden, Quad-Cities, and Zion stations are unreliable. More recent data collected at the three stations indicated background radioactivity concentrations of the following approximate average values: gross beta, 2,000 pCi/kg wet weight; strontium-90, 10 pCi/kg wet; cesium-137, <5 pCi/kg wet, and potassium-40, 2,000 pCi/kg wet.

bottom of the Mississippi River in the vicinity of the plant, the preoperational monitoring program included analyses of slime and sediments. Samples from the inlet canal, onsite and downstream offsite, near Pool 14 Lock and Dam, were analyzed for their radionuclide constituents. The results of the inlet canal analyses are not expected to be affected by the plant liquid discharges in the operational phase of the monitoring program. Consequently, they will indicate changes in the background radioactivity of the river. Furthermore, in comparison to the downstream analytical results for slime and sediments, the inlet canal data will provide baseline values from which the extent of increase in radioactivity downstream, attributable to the plant, will be determined.

Table 21 summarizes the 1970 preoperational environmental monitoring data for the Quad-Cities Nuclear Power Station (35).

Zion Nuclear Power Station

The Zion Nuclear Power Station is located in northeastern Illinois on the west shore of Lake Michigan, 40 miles north of Chicago and 42 miles south of Milwaukee, Wis. The station is approximately 1.7 miles east of the City of Zion (1970 population total, 17,268). It contains two pressurized water reactors each with rated net electrical output of 1,085 megawatts. Zion Units 1 and 2 will use Lake Michigan as the source for condenser cooling water and for dilution of the radioactive liquid discharges. Since the two units were under construction during 1970, they did not contribute to the environmental radioactivity in Illinois.

Zion Nuclear Power Station environmental monitoring program

During 1970, Commonwealth Edison Company, owner and operator of the Zion Station, initiated the preoperational phase of the station's environmental monitoring program. As part of this program, a special study was conducted to determine the tritium level of Lake Michigan in the vicinity of the station (36). In addition, an extensive survey of the lake was carried out during 1969-1970 by the Great Lakes Research Division of the University of

Michigan (6). In this study radiochemical analyses were performed on samples of the lake biota and the lake's concentration of major radionuclides was measured. The elements of the Zion station environmental monitoring program are given in table 22 (37). A brief description of the preoperational monitoring program and a summary of the findings for 1970 follow.

Background environmental radiation

Ion-chamber background radiation measurements were made weekly at nine locations in and around the Zion site. A summary of these measurements is provided in table 23. The mean external background radiation for all the monitoring stations was approximately 1.8 millirem per week. Extrapolated to a full year, this corresponds to an external background radiation level of approximately 94 millirems per year. Similar to the findings around the Quad-Cities Station, the average annual external background exposure onsite was about 82 millirems whereas the corresponding value offsite was 99 millirems.

Samples of well water, precipitation and deposition were collected and analyzed monthly while surface and drinking water were analyzed weekly. The monthly samples and composites of the weekly samples were evaluated for their tritium content. None of the samples showed tritium activity above the minimum detectable level. However, in a special study of Lake Michigan surface water in the vicinity of the Zion Station (36), it was found that the mean tritium concentration was 340 pCi/liter with a range of 311-374 pCi/liter (table 24). Furthermore, the following conclusions were made: (a) neither seasonal variations nor depth from which water samples were taken showed a statistically significant effect on the mean tritium concentration of the lake, (b) tritium concentrations in precipitation were greater than those of the lake, with a mean value of 521 pCi/liter and a range of 172-989 pCi/liter. Similarly, the gross beta radioactivity of precipitation showed a mean radioactivity concentration of 16.6 pCi/liter as compared to the lake's surface water having mean activity level of approximately 3 pCi/liter.

Table 21. Summary of the preoperational environmental monitoring data, Quad-Cities Nuclear Power Station, 1970^a

Sampling media and units	Number of samples ^b	Type of analysis	Radioactivity concentration		
			Maximum	Minimum	Mean
Airborne particulates..... (pCi/m ³)	154 (3) 36 (3)	Gross beta Gross alpha	0.52 ND	0.03 ND	0.16 ND
Ion-chamber..... (mrem/week)	732 (16)	Gross gamma	3.5	.6	1.8
TLD..... (mrem/a)	16 (16)	Gross gamma	120	80	97
Well water..... (pCi/liter)	36 (5)	Gross alpha Gross beta	2.0 5.6	ND ND	.35 2.13
Surface water..... (pCi/liter)	156 (3) 12 (3) 46 (3)	Gross alpha Gross beta Tritium Strontium-89 Strontium-90 Tritium	.91 6.4 ND ND 3.52 ND	ND 2.8 ND ND 1.90 ND	.52 4.7 ND ND 2.55 ND
Precipitation ^c (pCi/liter)	36 (3)	Gross alpha Gross beta	7.35 300	ND 4.8	1.4 39.1
Deposition ^c (pCi/m ² -month)	36 (3)	Gross alpha Gross beta	990 12,600	ND 40	67 1,391
Milk..... (pCi/liter)	24 (2)	Gross beta ^e Strontium-89 Strontium-90 Cesium-137 Strontium-90 ^b Iodine-131	960 ND 12.3 9.77 15.4 ND	313 ND 1.23 2.18 1.17 ND	683 ND 6.80 5.32 6.40 ND
Fish ^f (pCi/kg)	17 (1)	Gross alpha Gross beta Strontium-89 Strontium-90 Cesium-137 Gamma scan ^g	ND 9.9 ND ND .18 ND	ND .35 ND ND ND ND	ND 5.3 ND ND .70 ND
Vegetables ^h (pCi/kg)	29 (2)	Gross beta Strontium-89 Strontium-90 Cesium-137	70.6 ND .18 .11	5.65 ND ND ND	27 ND .35 .35
Vegetation ^h (pCi/kg)	14 (14)	Gross beta Strontium-89 Strontium-90 Gamma scan ^g	13,700 ND 820 ND	3,640 ND 470 ND	10,500 ND 590 ND
Grass ^h (pCi/kg)	24 (2)	Strontium-89 Strontium-90 Cesium-137	ND 2,370 1,628	ND 220 170	ND 1,130 652
Slime ^h (pCi/kg)	6 (2)	Gross alpha Gross beta Gamma scan ^g	2,400 13,000 ND	380 3,790 ND	855 10,304 ND
Soil ^h (pCi/kg)	2 (2)	Gross beta Strontium-89 Strontium-90 Cesium-137	3,370 ND 385 660	3,300 ND 257 290	3,335 ND 321 475
Sediments ^h (pCi/kg)	6 (2)	Gross alpha Gross beta Strontium-89 Strontium-90 Gamma scan ^g	1,300 5,740 ND 32.8 ND	320 550 ND 18 ND	649 1,871 ND 23 ND

^a Data taken from reference 35.^b Number in parentheses indicates the number of sampling locations.^c Quarterly composite samples.^d Semiannual composite samples.^e Samples included rain, snow and fallout deposition.^f Some of the samples were gamma scanned for iron-59, cobalt-60, zirconium-95, ruthenium-106, and cesium-137.^g Based on calibration with a strontium-yttrium standard. These figures are considered to be low because of reduced counter efficiency due to solids absorption.^h Reporting unit is pCi of strontium-90 per gram calcium.ⁱ Results reported per edible wet weight: wet/dry weight ~35.^j Samples included buffalo, perch, carp, catfish, and bluegills.^k Gamma scan for iron-59, cobalt-60, zirconium-95, ruthenium-106, and cesium-137.^l Analyses results reported for edible wet weight: wet/dry weight ~12. [Data unreliable (personal communication from Dr. John C. Golden, Commonwealth Edison Co.).]^m Samples included tomatoes, cabbage, cucumbers, corn, onions, bell peppers and others.ⁿ Analyses results based on dry weight: wet/dry ~3.5.^o Analyses results based on dry weight: wet/dry ~2.8.^p Analyses results based on dry weight.

ND, nondetectable. For minimum detectable levels see table 19.

Table 22. Zion Nuclear Power Station environmental monitoring program^a

Sample type	Number of sites	Frequency of collection	Type of analysis	Minimum detectable levels (MDL) and units ^b
Airborne particulates	13	Monthly Weekly	Gross alpha Gross beta Gamma scan ^c	0.001 pCi/m ³ 0.001 pCi/m ³ (^d) pCi/m ^{3d}
Airborne iodine-131	13	Biweekly	Iodine-131	.03 pCi/m ³
Ion-chambers	13	Weekly	Gross gamma	.6 mrem/week
TLD	13	Quarterly Annually	Gross gamma ^e Gross gamma ^e	.3 mrem/a .3 mrem/a
Well water	3	Quarterly	Gross alpha Gross beta Gamma scan ^f Strontium-89 ^g Strontium-90 ^g Cesium-137 ^g Radium-226 ^g	2 pCi/liter 2 pCi/liter (^d) pCi/liter .5 pCi/liter .5 pCi/liter 10 pCi/liter 10 pCi/liter
Drinking water	6	Weekly Semiannually ^h Quarterly ^h	Gross alpha Gross beta Gamma scan ^f Strontium-89 Strontium-90 Tritium	2 pCi/liter 2 pCi/liter (^d) pCi/liter .5 pCi/liter .5 pCi/liter 1,000 pCi/liter
Surface water	5	Weekly Semiannually ^h Quarterly ^h	Gross alpha Gross beta Gamma scan ^f Strontium-89 Strontium-90 Tritium	2 pCi/liter 2 pCi/liter (^d) pCi/liter .5 pCi/liter .5 pCi/liter 1,000 pCi/liter
Precipitation and deposition ^b	3	Monthly	Gross alpha Gross beta Tritium	20 pCi/m ² 20 pCi/m ² 1,000 pCi/liter
Milk	2	Weekly ⁱ Monthly ⁱ	Cesium-137 Barium-140 Iodine-131 Strontium-89 Strontium-90 Calcium	10 pCi/liter 10 pCi/liter 10 pCi/liter 1 pCi/liter 1 pCi/liter g/liter
Fish ^j	2	3 annually	Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg (^d) pCi/kg 5 pCi/kg 5 pCi/kg
Vegetables	Varies	Annually	Gross alpha Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg 20 pCi/kg (^d) pCi/kg 5 pCi/kg 5 pCi/kg
Grass	2	Monthly ^k	Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg (^d) pCi/kg 5 pCi/kg 5 pCi/kg
Cattle feed	2	Monthly	Gross beta Cesium-137 Strontium-89 Strontium-90	20 pCi/kg 10 pCi/kg 5 pCi/kg 5 pCi/kg
Periphyton (slime)	2	3 Annually	Gross beta Gamma scan	20 pCi/kg (^d) pCi/kg
Benthic organisms	2	Semiannually	Gross beta Gamma scan	(^m) pCi/kg (^m) pCi/kg
Soil	2	Semiannually	Gross beta Gamma scan Strontium-89 Strontium-90	20 pCi/kg (^d) pCi/kg 5 pCi/kg 5 pCi/kg
Sediment	5	Semiannually	Gross alpha Gross beta Strontium-89 Strontium-90	20 pCi/kg 20 pCi/kg 5 pCi/kg 5 pCi/kg

^a Taken from reference 37.^b MDL, minimum detectable level. Since the MDL depends on a number of factors such as analytical procedures, sample size, counting instrumentation, etc., the values specified are not theoretical levels of detection but rather approximate values of sensitivity which give an approximate level of detectability.^c Gamma scan performed on sample with gross beta ≥ 1.0 pCi/m³.^d MDL is a function of the spectrum complexity, sample size, counting geometry and instrumentation.^e Beta radiation is not detected because of encapsulation of the TLD's.^f Analysis performed when gross beta ≥ 5 times the last quarterly average at the specific location from which the samples are collected.^g Composites of weekly samples.^h Rain, snow and dry fallout deposition.ⁱ Weekly between April and September; monthly between October and March.^j Samples are split into whole and fillet.^k Samples collected between April and September.^m MDL depends on size of available sample.

Table 23. Summary of external gamma radiation background, Zion Nuclear Power Station, 1970^a

Sampling location	Distance from station (miles)	Ion-chamber measurements				
		Number of readings ^b	Maximum (mrem/week)	Minimum (mrem/week)	Mean (mrem/week)	Annual exposure ^c (mrem/a)
Onsite:						
Zion #1.....	0.25 S	21	2.2	1.1	1.4	75
Zion #2.....	.2 W	21	2.3	1.2	1.7	87
Zion #3.....	.5 NW	21	2.2	1.1	1.6	85
Offsite:						
Winthrop Harbor #6.....	2.5 N	10	2.2	1.5	1.7	90
Kenosha Road Farm #7.....	4 W	8	4.5	1.7	2.3	119
Waukegan #8.....	5 S	13	3.4	1.2	1.8	94
Zion #9.....	5 W	21	2.7	1.3	1.8	94
North Chicago #10.....	8 S	22	3.0	1.2	1.7	88
Flood Farm #12.....	11 SW	10	3.0	1.5	2.1	110
Summary: Onsite.....		63	2.3	1.1	1.6	82
Offsite.....		62	4.5	1.2	1.9	99

^a Data taken from reference 38.

^b Sample collection frequency on weekly basis during the second half of 1970.

^c Extrapolated for 52 weeks based on number of readings at each station.

Table 24. Summary of tritium concentration in Lake Michigan in the vicinity of Zion Nuclear Power Station, 1970^a

Sampling location	Distance from station (feet)	Number of samples ^b	Radioactivity concentration (pCi/liter)		
			Maximum	Minimum	Mean
Kenosha water works.....	22,000 N	12	363	320	342
Lake County water works ^b	2,000 NE	12	373	311	341
Surface water.....	660 E	12	360	315	341
12'-20' deep.....	660 E	12	365	322	344
Surface water.....	2,000 E	12	374	321	344
22'-35' deep.....	2,000 E	12	367	321	344
Surface water.....	6,000 E	12	367	331	347
37'-40' deep.....	6,000 E	12	371	329	342
Illinois beach state park ^c	6,700 S	12	357	324	342
Waukegan water intake.....	32,000 S	12	359	324	342
Summary.....		120	374	311	343

^a Data taken from reference 36.

^b Samples collected from a depth of 23 to 30 feet.

^c Samples collected from the surface water 10 to 15 feet offshore.

Milk samples were collected monthly from two farms and analyzed for the fallout-originated radionuclides; strontium-89, strontium-90, cesium-137 and iodine-131. In addition, the potassium-40 content in milk was also determined. This radioisotope of potassium is one of the naturally occurring terrestrial sources of radiation which contributes a major portion of the internal radiation exposure to the population. Table 25 summarizes the milk analyses data as well as data from analyses of other media during 1970 as part of the preoperational environmental monitoring program (38).

The Lake Michigan study, sponsored by six utilities with nuclear power stations located along the lake shores, measured the level of radioactivity in the lake's water, sediments, benthos, zooplankton, phytoplankton and fish (6). A total of 370 samples was collected from 50 sampling stations covering the entire lake. The study provided background radiological data for evaluating the cumulative effect of the power operation of all the nuclear power stations along Lake Michigan's shores. A total of 10 nuclear power reactors is scheduled to operate by 1975 along the lake's shores and

Table 25. Summary of the preoperational environmental monitoring data, Zion Nuclear Power Station, 1970^a

Sampling media and units	Number of samples ^b	Type of analysis	Radioactivity concentration		
			Maximum	Minimum	Mean
Airborne particulates (pCi/m ³)	129 (5)	Gross alpha Gross beta	ND 0.46	ND 0.03	ND 0.13
Airborne iodine-131 (pCi/m ³)	11 (5)	Iodine-131	.03	ND	.01
Ion-chamber (mrem/week)	147 (9)	Gross gamma	4.5	1.1	1.8
Well water (pCi/liter)	15 (3)	Gross alpha Gross beta Tritium	4.3 7.8 ND	ND ND ND	.5 1.3 ND
Surface water (pCi/liter)	95 (4)	Gross alpha Gross beta Tritium	5.3 11 ND	ND ND ND	.5 2.9 ND
Drinking water (pCi/liter)	102 (5)	Gross alpha Gross beta Tritium	4.6 11 ND	ND ND ND	.3 2.4 ND
Precipitation (pCi/liter)	16 (3)	Gross alpha Gross beta Tritium	7.4 48 ND	ND ND ND	.5 16.6 ND
Deposition (pCi/m ² -month)	16 (3)	Gross alpha Gross beta	48 2,000	ND ND	3 264
Milk (pCi/liter)	12 (2)	Potassium-40 Strontium-89 Strontium-90 Cesium-137 Iodine-131 Strontium-90 ^d	2,140 ND 15.4 16.5 ND 13.7	1,070 ND 3.61 3.49 ND 1.23	1,500 ND 7.33 7.40 ND 6.41
Vegetables ^e (pCi/kg)	9 (3)	Gross alpha Gross beta Strontium-90	3,700 34,000 800	ND 14,000 140	766 21,600 430
Feedcrops ^e (pCi/kg)	3 (3)	Strontium-89 Strontium-90 Cesium-137	ND 170 380	ND 100 170	ND 140 260
Grass ^f (pCi/kg)	19 (12)	Strontium-89 Strontium-90 Cesium-137	ND 1,530 1,010	ND 190 190	ND 840 540
Slimes ^g (pCi/kg)	4 (4)	Gross alpha Gross beta Gamma scan	840 8,090 ND	350 4,040 ND	578 5,805 ND
Soil ^h (pCi/kg)	3 (3)	Gross alpha Gross beta Strontium-89 Strontium-90 Cesium-137 Gamma scan	2,300 6,000 ND 386 780 ND	1,600 1,600 ND 270 360 ND	1,900 3,500 ND 319 520 ND
Sediments ⁱ (pCi/kg)	3 (1)	Cesium-137 Radium-226 Potassium-40	230 2,060 9,610	ND 1,400 8,490	133 1,720 8,990

^a Data taken from reference 38.^b Number in parentheses indicates number of sampling locations.^c Monthly composite samples.^d Reporting unit is pCi of strontium-90 per gram of calcium.^e Analysis results based on dry weight: wet/dry ~ 19. [Data unreliable (personal communication from Dr. John C. Golden, Commonwealth Edison Co.).]^f Samples included tomatoes, onions, green beans, and cabbage.^g Analysis results based on dry weight.^h Samples included corn and soybeans.ⁱ Analysis results based on dry weight: wet/dry ~ 3.5.^j Sampled during the Lake Michigan Study (6) at a sampling station 1-mile east of the Zion Station

ND, nondetectable. For minimum detectable levels see table 22.

use the lake's water for dissipating excess heat and for diluting radioactive waste discharges.

Among the findings of the Lake Michigan study, it is worth noting that the fish analyzed showed cesium-137 and zinc-65 concentrations far greater than those found in the water. Concentration factors ranged from 100 to 900

for cesium-137 and from 40 to 30,000 for zinc-65.^a This points out a potentially important

^a Dr. John C. Golden, staff radioecologist, Commonwealth Edison Co., in a personal communication pointed out that a reexamination of the gamma-ray spectra by the authors of the original report showed that zinc-65 was not present in the fish. The reported values in the report are believed to represent residual counts after spectrum stripping.

source of population exposure via the food-chain pathway. In addition, it was found that an estimated two-thirds of the lake's inventory of cesium-137 is concentrated in the bottom sediments having a concentration of 1.4 pCi/g dry weight. Other media such as benthic organisms and phytoplankton also showed reconcentration factors, but of considerably lower levels.

Other radiation sources

As mentioned earlier in this report, the major manmade source of radiation exposure to the population is from medical uses of x-ray devices. Table 26 gives the estimated number of dental and medical x-ray units in Illinois for 1970 (39). It also provides the estimated number of a variety of other radiation sources utilized by educational and governmental laboratories and by industry. The sundry other sources are generally located in a controlled access area. The exposure from these sources is limited almost entirely to the individuals using them and contribute primarily to occupational radiation dose.

The seven reactors referred to in table 26 include six reactors of various types located at the Argonne National Laboratory (ANL) (table 27) and one reactor operated by the University of Illinois.

Table 26. Miscellaneous radiation sources in Illinois, 1970^a

Type of facility	Estimated number of units
Dental x ray.....	5,544
Medical x ray:	
Diagnostic.....	4,103
Therapeutic.....	347
Industrial x ray.....	473
Particle accelerators.....	17
Byproducts, source and special nuclear material licenses.....	677
Radium—Radon program activities.....	56
Miscellaneous reactors.....	7

^a Data taken from reference 39.

As mentioned earlier, results of the environmental surveillance program in and around the Argonne National Laboratory are reported semiannually (4) and summarized in *Radiation Data and Reports* (2,3). The 1970 data indicates that Argonne's contribution to the environmental radioactivity, offsite, was limited

primarily to an increase in the tritium concentration of the Sawmill Creek water and the Des Plaines River in the immediate vicinity of the laboratory. Sawmill Creek is a stream that flows through the laboratory site into the Des Plaines River. The increase in the tritium level offsite resulting from the Argonne's discharges was a small fraction (less than 0.02 percent) of the applicable AEC limit. From the standpoint of population exposure, the ANL discharges contributed primarily to occupational exposure.

Table 27. Nuclear facilities at Argonne National Laboratory, 1970^a

Name of facility	Reactor type	Power kW(t)	Year of startup
Argonne Research Reactor.....	Heavy water	5,000	1954
Argonne National Laboratory..	Homogeneous solid Graphite/water	Negligible	1957
Argonne Nuclear Assembly ^b		10	1957
Argonne Thermal Source Reactor.....	Thermal Tank	10	1957
Biological Research Reactor.....		200	1964
Argonne Power Research Reactor.....	Graphite/water	250	^c 1962

^a Taken from reference 39. The reactors are owned by the Atomic Energy Commission.

^b For University training.

^c Shut down during 1970.

The seventh reactor in the state is an advanced TRIGA research reactor with a rated maximum power of 1.5 megawatt owned by the University of Illinois and located on campus in Urbana, Ill. The limiting radionuclide discharged from this type of facility is argon-41 which is a beta emitter having a 1.8 hour half-life. It is produced by neutron activation of stable argon-40, a natural constituent of the atmosphere. Based on experience gained from nine college-based TRIGA research reactors, radioactive wastes discharged from these low power facilities are generally less than 1 curie per year and do not contribute significantly to the general population exposure (40).

Population exposure in Illinois

In the 1968 special study of the Dresden Unit 1 effluents (9), the critical exposure pathway was determined to be via external radiation from the short-lived isotopes of the radioactive noble gases, krypton and xenon. Similarly, the 1970 results of the Dresden Station environmental

monitoring program indicated that external exposure from the station's gaseous discharges was the major contributor to the population dose in the vicinity of the station. The average annual increase in dose from external exposure, offsite, 1 to 2 miles from the station, was approximately 29 millirems, while the corresponding increase at locations 2 to 16 miles from the station, based on ion-chamber and TLD measurements, was about 7 millirems. The exposure pathway via external radiation from the gaseous effluents was the only pathway for which direct measurements yielded estimated exposure values. Radioactivity levels along other potential exposure pathways were either below detectable limits or indicated contributions of radionuclides from natural and fallout origins. In the few instances where the measurements indicated the presence of radionuclides of reactor origin, the measured increases in radioactivity were marginally above background.

Blanchard et al. (21,41) calculated the maximum potential dose in the vicinity of the Dresden Station via seven principal pathways. The dose rate calculations were based on the radionuclide release rates measured in the stack during 1968 and the concentrations measured in the condenser coolant discharge canal (9). Each pathway was considered individually for the major radionuclides found in the effluents and the dose resulting from each nuclide was estimated. The exposure pathways originating from the stack discharges included the ingestion of milk, beef, and leafy vegetables, inhalation of airborne halogens and particulates and the external exposure pathway. The two pathways whose radionuclides originated from the liquid discharges were drinking water and ingestion of fish.

In order to provide a measure of the relative importance of the principal exposure pathways for which direct measurements were not available, and to identify the critical radionuclides for each of these pathways, the estimated maximum potential dose during 1970 from the critical radionuclides to an individual offsite is given in table 28. The estimated dose rates (dose from external exposure excluded) are calculated from values estimated by Blanchard

Table 28. Maximum potential dose from critical radionuclides in each pathway, 1970^a

Pathway	Critical radionuclide	Critical organ	Estimated dose rate (mrem/a)
Atmosphere-external.....	Gaseous fission products	Whole body	32
Milk.....	Iodine-131	Thyroid	31
Leafy vegetable.....	Iodine-131	Thyroid	7.2
Drinking water.....	Iodine-131	Thyroid	3.2
Fish.....	Iodine-131	Thyroid	.4
Beef.....	Cesium-137	Whole body	.033
Atmosphere-inhalation.....	Iodine-131	Thyroid	.013

^a Estimated dose rates are calculated based on estimated values in references 21, 41.

^b Value based on the gaseous effluents discharged during 1970.

et al. In arriving at the dose rates for 1970 it was assumed that the pathways, the transfer coefficients, and dilution factors used in calculating the 1968 estimated dose rates were applicable to the discharges of 1970. In addition, it was assumed that the gaseous and liquid effluents radionuclide composition as well as the relative contribution of each nuclide to the total activity were similar in 1970 to the corresponding values measured during 1968. In light of these assumptions and the nature of the original dose estimates, the values for 1970 are meaningful only as indicators of the relative importance and order of magnitude of the dose rates from the critical radionuclide in each of the pathways. The estimated values represent upper limits of potential dose rates to an individual offsite as a result of the Dresden Station discharges. In five of the pathways, iodine-131 is found to be the critical radionuclide. In the case of exposure via the consumption of beef, cesium-137 is found to be the critical nuclide.

Table 29 summarizes the estimated annual dose to the critical organs, for the major radionuclides in the Dresden effluents. It also summarizes the percentages of the critical organs' annual dose relative to the Radiation Protec-

Table 29. Estimated annual dose to critical organs, 1970

Critical organ	Estimated dose (mrem/a)	RPG ^a (mrem/a)	Percent of RPG
Whole body-external.....	32	170	18
Thyroid.....	42	500	8
Bone.....	.54	170	.3
Whole body-internal.....	.34	170	.2
GI (LLI) ^b07	500	.01

^a RPG, Radiation Protection Guide (48).

^b GI (LLI), gastrointestinal tract (lower large intestine).

^c Value based on International Committee on Radiation Protection (ICRP) (49).

tion Guide (RPG) (42) dose limits. Since no person is likely to be exposed to all the pathways, the estimated values represent maximum dose levels and indicate the relative dose rates for the various critical organs. Results indicate that the whole body receives the greatest percentage of the RPG annual dose limit.

The contribution to the population exposure from all natural and manmade sources is summarized in table 30 (44). The dose values corresponding to the natural radiation from external sources are based on calculations by Oakley (45) in which the natural radiation exposure in the United States was estimated from the Aerial Radiological Measurement Surveys (ARMS) conducted by the Atomic Energy Commission over major areas of the United States. The population exposure from natural external radiation in Illinois was based on measurements taken at 12 population centers with a total of more than 10,081,000 people. The exposures in the study were weighted by the population at each of the survey areas. The average dose from natural external radiation of approximately 90 millirems per year esti-

mated by Oakley is in good agreement with the ion-chamber external background measurements taken during the preoperational surveillance program of the Quad-Cities and the Zion Stations (tables 20 and 23).

To place the various manmade sources of radiation in perspective, the percentages of the annual dose from each source relative to the total dose from natural radiation are tabulated. It is worth noting that the increase in the genetically significant dose from manmade sources is approximately 60 percent of the dose corresponding to natural background. The major portion of this increase (approximately 53 percent), is due to medical uses of radiation. For the special case of the population within 16 miles from the Dresden Station, totaling approximately 150,000 people, there was an apparent additional increase during 1970 in the whole body genetically significant dose, above the dose from natural radiation, of approximately 6 percent attributable to the Dresden Station discharges.

Summary and conclusions

Dresden Nuclear Power Station Units 1 and 2 were the only power reactors operating in Illinois during 1970. Dresden Station Unit 3, Quad-Cities Station Units 1 and 2, and Zion Station Units 1 and 2 were under construction during this period. They are all scheduled to be operational by 1973.

Based on ion-chamber and TLD measurements made in the preoperational environmental monitoring programs of the Quad-Cities and Zion Stations, the average background external exposure onsite, at both stations, was approximately 83 millirems per year. The corresponding average value, offsite, was about 98 millirems per year.

Dresden Unit 1 average annual release of noble and activation gases for the past 11 years was approximately 390,000 curies per year, which is 2.2 percent of the plant technical specification limit. For the same period Unit 1 average annual release via the liquid waste was 5.5 curies per year or 17 percent of the applicable limit. The releases of radioactivity from Unit 1 during 1970 suggest that the plant discharges leveled off after reaching a peak in

Table 30. Estimated average annual genetically significant dose to the population in Illinois, 1970

Source of radiation	Annual dose ^a (mrem/a)	Percent of natural radiation
Natural radiation		
External sources:		
Terrestrial gamma radiation.....	b43	37
Cosmic radiation.....	b47	41
Internal sources:		
Potassium-40.....	17	15
Carbon-14.....	1	.9
Rubidium-87.....	.6	.5
Polonium-210.....	3	2.6
Radon-222.....	3	2.6
Subtotal (rounded).....	115	100
Residual fallout from nuclear tests:		
Cesium-137.....	1.3	1.1
Carbon-14.....	.6	.5
Strontium-90.....	3.2	2.8
Subtotal.....	5.1	4.5
Medical uses of radiation:		
Medical and dental radiology.....	55	48
Radiation therapy.....	5	4.4
Radiopharmaceutical use.....	c1.2	1
Subtotal (rounded).....	61	53
Occupational.....	~1	.9
Miscellaneous other sources ^d	2	1.7
Total.....	184	160
Residents, Dresden vicinity, <16-miles....	7	6.1

^a Annual dose values are taken from reference 44, except as noted.

^b Values based on reference 45.

^c Value taken from reference 46.

^d Miscellaneous other sources include: radiation from TV, luminous dials, commercial appliances, air transportation, etc.

1969. Dresden Unit 2 in its first year of operation discharged 12.8 curies via the liquid waste and 250,000 curies via the gaseous waste. These correspond to 15 and 1.1 percent, respectively, of the plant technical specification limits.

A comparison between the radioactivity levels in environmental media near the Dresden Station and the background radioactivity levels measured in the preoperational phases of the Quad-Cities and Zion Stations indicated that the effect of the Dresden discharges on most environmental media was scarcely distinguishable from the radioactivity resulting from fallout of atmospheric nuclear tests and from natural sources. The only apparent increase in environmental radioactivity attributable to the Dresden Station operations during 1970 was an approximately 6 percent increase in the radiation dose in the vicinity of the station relative to the natural background radiation in Illinois of 115 millirems per year.

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SECTION I. MILK AND FOOD

Milk Surveillance, July 1972

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the network presently reporting in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (1). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (2) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-

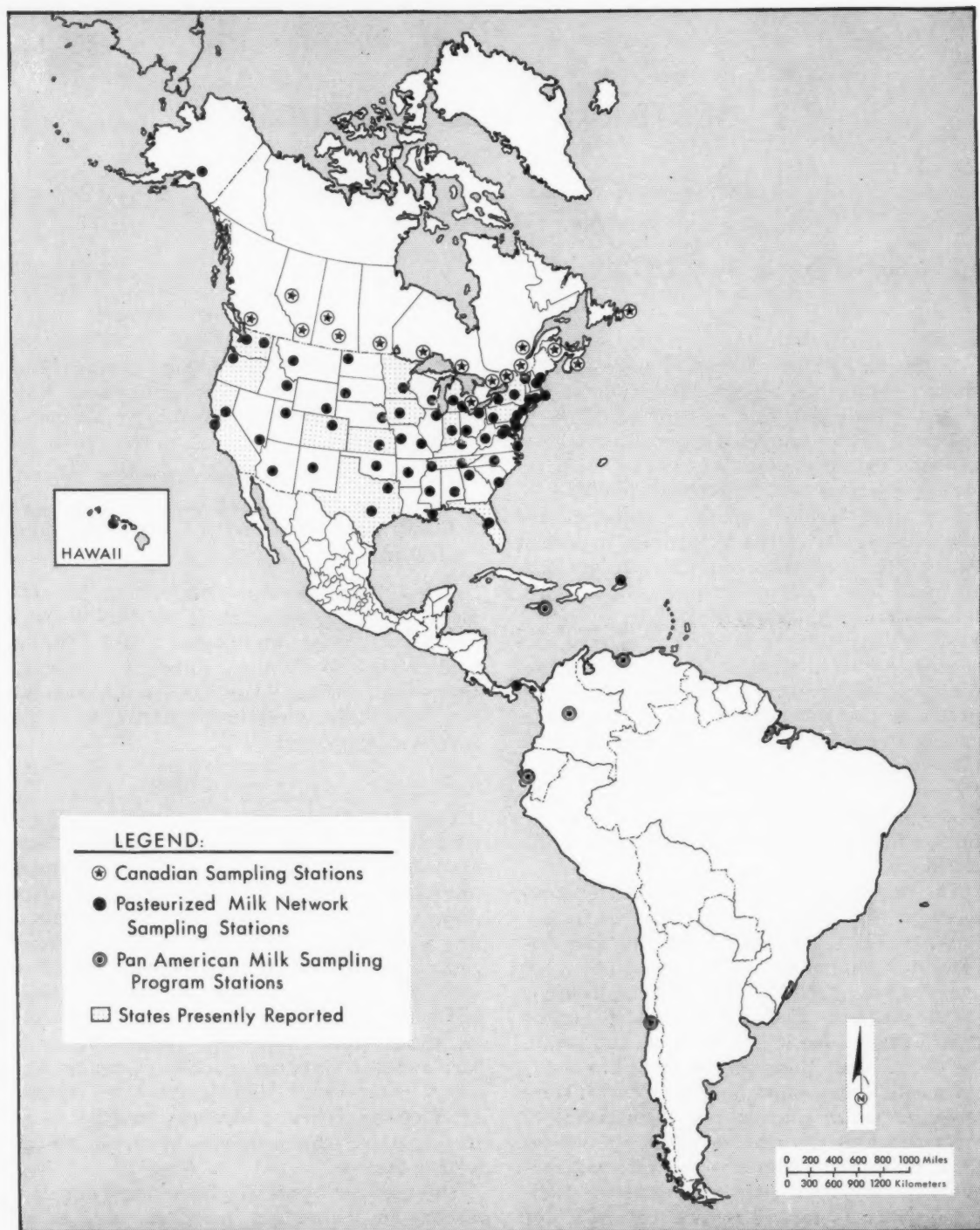


Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (3) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (4).

The most recent study was conducted during July 1971 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (5). Of the 17 laboratories producing data for the networks reporting in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. Considerable improvement has been made in the accuracy of the analyses of all radionuclides compared to the results of previous studies. Some

improvement is still needed in the technique for determining the strontium-90 results. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category				Experimental 2σ error (pCi/liter)
	Acceptable ^a	Warning level ^b	Unacceptable ^c	Total	
Iodine-131 (69 pCi/liter).....	13 (100%)	0	0	13	6
Cesium-137 (52 pCi/liter).....	12 (92%)	1 (8%)	0	13	6
Strontium-89 (31 pCi/liter).....	9 (90%)	1 (10%)	0	10	6
Strontium-90 (41.6 pCi/liter).....	9 (69%)	1 (8%)	3 (23%)	13	2.4

^a Measured concentration equal to or within 2σ of the known concentration.

^b Measured concentration outside 2σ and equal to or within 3σ of the known concentration.

^c Measured concentration outside 3σ of the known concentration.

reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (6) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (6). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2 standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (3). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, par-

ticularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range has also been reported by the networks (3). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels \geq 50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels \geq 20 pCi/liter;
Iodine-131	4-10 pCi/liter for levels <100 pCi/liter; 4-10% for levels \geq 100 pCi/liter.
Cesium-137	
Barium-140	

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiation Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radio-logical Health Data and Reports*.

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiation Data and Reports*. The relationship between the PMN stations and the State stations is shown in figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated

Table 2. Concentrations of radionuclides in milk for July 1972 and 12-month period August 1971 through July 1972

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)				
			Strontium-90		Cesium-137		
			Monthly average ^b	12-month average	Monthly average ^b	12-month average	
UNITED STATES:							
Ala:	Montgomery ^c	P	5	7	0	9	
Alaska:	Palmer ^c	P	4	5	11	11	
Ariz:	Phoenix ^c	P	0	0	0	0	
Ark:	Little Rock ^c	P	10	12	0	8	
Calif:	Sacramento ^c	P	0	1	0	0	
	San Francisco ^c	P	0	1	0	0	
	Del Norte	P	13	12	0	11	
	Fresno	P	0	2	0	5	
	Humboldt	P	3	4	0	8	
	Los Angeles	P	0	2	0	5	
	Mendocino	P	5	5	0	7	
	Sacramento	P	0	2	0	6	
	San Diego	P	0	1	0	4	
	Santa Clara	P	0	1	0	7	
	Shasta	P	2	3	0	8	
	Sonoma	P	2	2	0	7	
Colo:	Denver ^c	P	7	5	0	4	
	East	R	NS		NS	40	
	Northeast	R	NA		(2)	40	
	Northwest	R	NA		40	40	
	South Central	R	NS		NS	40	
	Southeast	R	NA		40	40	
	Southwest	R	NA		40	40	
	West	R	NA		40	5	
Conn:	Hartford ^c	P	7	6	21	8	
	Central	P	8	7	10	13	
Del:	Wilmington ^c	P	11	8	14	6	
D.C:	Washington ^c	P	8	7	13	6	
Fla:	Tampa ^c	P	4	5	41	40	
	Central	R	6	6	54	40	
	North	R	5	10	10	19	
	Northeast	R	3	6	32	34	
	Southeast	R	6	6	34	56	
	Tampa Bay area	P	4	6	37	37	
	West	R	4	9	7	18	
Ga:	Atlanta ^c	P	8	9	14	14	
Hawaii:	Honolulu ^c	P	0	3	0	2	
Idaho:	Idaho Falls ^c	P	4	5	0	0	
Ill:	Chicago ^c	P	3	6	12	11	
Ind:	Indianapolis ^c	P	3	6	0	3	
	Central	P	6	7	0	12	
	Northeast	P	6	7	0	12	
	Northwest	P	8	8	0	15	
	Southeast	P	9	8	0	13	
	Southwest	P	9	9	15	13	
Iowa:	Des Moines ^c	P	5	4	0	1	
	Iowa City	P	6	7	15	10	
	Des Moines	P	6	6	12	10	
	Little Cedar	P	NS	6	NS	6	
	Spencer	P	6	7	11	12	
Kans:	Wichita ^c	P	8	8	0	1	
	Coffeyville	P	7	8	0	12	
	Dodge City	P	7	5	0	9	
	Falls City, Nebr.	R	6	3	11	8	
	Hays	P	7	9	0	8	
	Kansas City	P	6	8	0	11	
	Topeka	P	7	7	0	9	
	Wichita	P	8	9	0	9	
Ky:	Louisville ^c	P	7	8	0	8	
La:	New Orleans ^c	P	16	14	11	11	
Maine:	Portland ^c	P	6	6	18	20	
Md:	Baltimore ^c	P	7	7	0	4	
Mass:	Boston ^c	P	9	7	13	11	
Mich:	Detroit ^c	P	7	7	0	9	
	Grand Rapids ^c	P	6	7	0	7	
	Bay City	P	NS	5	NS	13	
	Charlevoix	P	4	8	16 (4)	14	
	Detroit	P	4	5	0	10	
	Grand Rapids	P	NS	5	NS	10	
	Lansing	P	6	7	0	12	
	Marquette	P	3	7	12 (3)	22	
	Monroe	P	3	3	0 (3)	4	
	South Haven	P	5	5	13 (4)	9	
Minn:	Minneapolis ^c	P	8	8	16	15	
	Bemidji	P	5	8	13	19	
	Duluth	P	12	16	31	28	
	Fergus Falls	P	6	8	13	16	
	Little Falls	P	26	17	123	38	
	Mankato	P	4	5	8	12	
	Minneapolis	P	8	12	14	17	

Footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for July 1972 and 12-month period August 1971 through July 1972—continued

Sampling location		Type of sample ^a	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average ^b	12-month average	Monthly average ^b	12-month average
UNITED STATES:—continued						
Minn:	Rochester.....	P	6	8	12	14
	Worthington.....	P	5	6	11	12
Miss:	Jackson ^c	P	8	10	11	10
Mo:	Kansas City ^c	P	7	7	0	5
	St. Louis ^c	P	6	7	11	5
Mont:	Helena ^c	P	6	5	0	5
Nebr:	Omaha ^c	P	4	2	0	0
Nev:	Las Vegas ^c	P	3	2	0	0
N.H:	Manchester ^c	P	8	8	15	17
N.J:	Trenton ^c	P	6	7	0	5
N. Mex:	Albuquerque ^c	P	0	2	0	0
N.Y:	Buffalo ^c	P	7	6	40	7
	New York City ^c	P	12	8	40	8
	Syracuse ^c	P	6	7	40	8
	Albany.....	P	6	6	40 (3)	40
	Buffalo.....	P	NA	NA	40	40
	Massena.....	P	NA	NA	40	40
	New York City.....	P	NA	NA	13	0
	Syracuse.....	P	0	3	0	0
N.C:	Charlotte ^c	P	10	10	0	8
N. Dak:	Minot ^c	P	10	9	14	14
Ohio:	Cincinnati ^c	P	7	7	0	3
	Cleveland ^c	P	6	6	0	6
Okla:	Oklahoma City ^c	P	5	5	0	6
Oreg:	Portland ^c	P	NA	6	18	6
	Baker.....	P	4	1	40	40
	Coos Bay.....	P	6	1	40	3
	Eugene.....	P	3	0	40	1
	Medford.....	P	NS	1	40	4
	Portland composite.....	P	7	1	18	6
	Portland local.....	P	8	2	40	8
	Redmond.....	P	4	1	40	40
	Tillamook.....	P	9	1	20	12
Pa:	Philadelphia ^c	P	8	7	0	5
	Pittsburgh ^c	P	10	9	14	6
	Dauphin.....	P	5	7	0	12
	Erie.....	P	10	7	13	12
	Philadelphia.....	P	6	5	0	12
	Pittsburgh.....	P	6	6	18	14
R.I:	Providence ^c	P	5	6	15	11
S.C:	Charleston ^c	P	7	9	14	14
S. Dak:	Rapid City ^c	P	8	7	0	5
Tenn:	Chattanooga ^c	P	11	8	11	9
	Memphis ^c	P	NA	7	0	3
	Chattanooga.....	P	11	10	22	13
	Clinton.....	R	9	9	0	12
	Fayetteville.....	R	10	9	10 (2)	6
	Kingston.....	R	8	9	14 (2)	9
	Knoxville.....	P	8	8	12 (2)	10
	Lawrenceburg.....	P	7	8	18	9
	Nashville.....	P	7	8	0	7
	Pulaski.....	R	7	7	6 (2)	8
Tex:	Austin ^c	P	3	3	0	0
	Dallas ^c	P	6	6	0	0
	Amarillo.....	R	NA	NA	NA	NA
	Corpus Christi.....	R	NA	NA	NA	NA
	El Paso.....	R	NA	NA	NA	NA
	Fort Worth.....	R	NA	NA	NA	NA
	Harlingen.....	R	NA	NA	NA	NA
	Houston.....	R	NA	NA	NA	NA
	Lubbock.....	R	NA	NA	NA	NA
	Midland.....	R	NA	NA	NA	NA
	San Antonio.....	R	NA	NA	NA	NA
	Texarkana.....	R	NA	NA	NA	NA
	Uvalde.....	R	NA	NA	NA	NA
	Wichita Falls.....	R	NA	NA	NA	NA
Utah:	Salt Lake City ^c	P	3	4	11	5
Vt:	Burlington ^c	P	8	6	11	10
Va:	Norfolk ^c	P	9	8	0	6
Wash:	Seattle ^c	P	9	5	0	5
	Spokane ^c	P	4	5	11	8
	Benton County.....	R	0	1	0	0
	Franklin County.....	R	NS	1	NS	2
	Longview.....	R	6	0	0	0
	Sandpoint, Idaho.....	R	14	12	14	18
	Skagit County.....	R	9	8	12	6
W. Va:	Charleston ^c	P	10	8	15	5
Wisc:	Milwaukee ^c	P	4	5	0	6
Wyo:	Laramie ^c	P	5	4	0	2

Footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for July 1972 and 12-month period August 1971 through July 1972—continued

Sampling location	Type of sample ^a	Radionuclide concentration (pCi/liter)			
		Strontium-90		Cesium-137	
		Monthly average ^b	12-month average	Monthly average ^b	12-month average
CANADA:					
Alberta: Calgary.....	P	NA		11	17
Edmonton.....	P	NA		28	26
British Columbia: Vancouver.....	P	NA		18	25
Manitoba: Winnipeg.....	P	NA		17	22
New Brunswick: Fredericton.....	P	NA		NA	
Newfoundland: St. John's.....	P	NA		39	27
Nova Scotia: Halifax.....	P	NA		21	22
Ontario: Ottawa.....	P	NA		10	12
Sault Ste. Marie.....	P	NA		22	25
Thunder Bay.....	P	NA		17	22
Toronto.....	P	NA		12	12
Windsor.....	P	NA		10	9
Quebec: Montreal.....	P	NA		13	15
Quebec.....	P	NA		27	27
Saskatchewan: Regina.....	P	NA		13	17
Saskatoon.....	P	NA		17	17
CENTRAL AND SOUTH AMERICA:					
Canal Zone: Cristobal ^c	P	3	1	28	9
Chile: Santiago.....	P	6	1	12	2
Colombia: Bogota.....	P	0	1	0	0
Ecuador: Guayaquil.....	P	0	0	0	0
Jamaica: Kingston.....	P	0	4	26	66
Puerto Rico: San Juan ^c	P	0	3	0	7
Venezuela: Caracas.....	P	2	1	0	0
PMN network average ^e		6	6	6	7

^a P, pasteurized milk.

R, raw milk.

^b When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

^c Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

^d The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Cesium-137: Colorado—25 pCi/liter
New York—20 pCi/liter
Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

^e This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote ^c.

NA, no analysis.

NS, no sample collected.

using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate

criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for July 1972 and the 12-month period, August 1971 to July 1972. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140

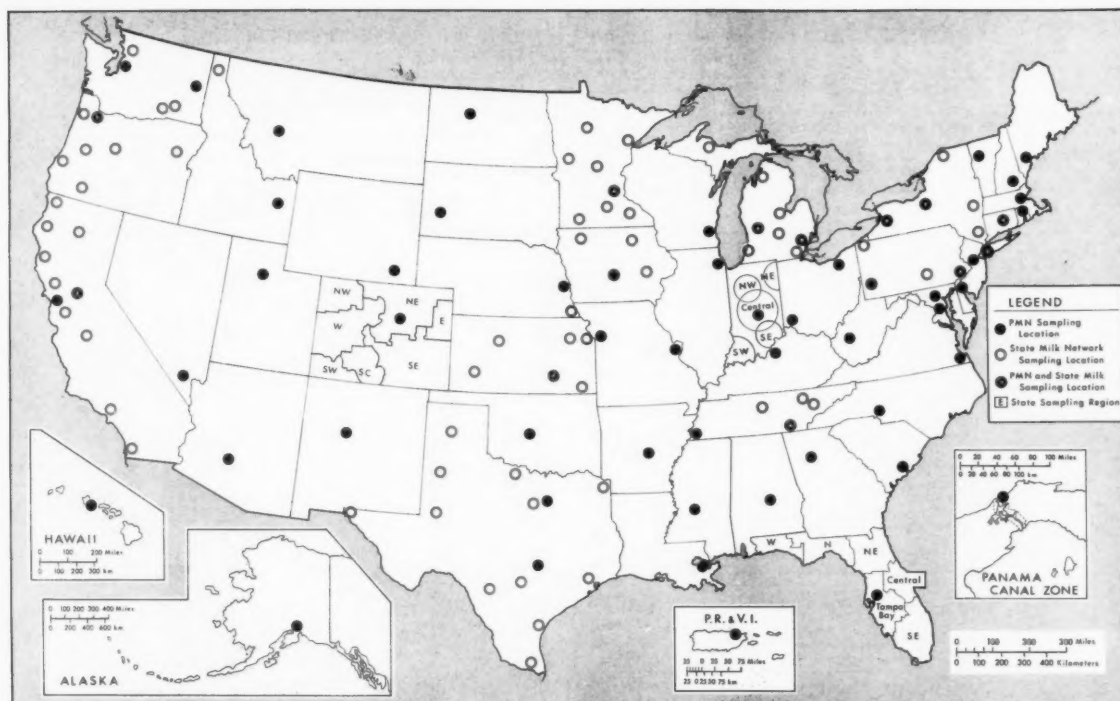


Figure 2. State and PMN milk sampling stations in the United States

data have been omitted from table 2 since levels at the great majority of the stations for July 1972 were below the respective practical reporting levels. Table 3 gives monthly averages for those stations at which strontium-89, iodine-131, and barium-140 were detected.

Strontium-90 monthly averages ranged from 0 to 26 pCi/liter in the United States for July 1972 and the highest 12-month average was 17 pCi/liter (Little Falls, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 123 pCi/liter in the United States for July 1972, and the highest 12-month average was 56 pCi/liter (Southeast Florida) representing 1.6 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular

interest are the consistently higher cesium-137 levels that have been observed in Florida (7) and Jamaica.

Table 3. Strontium-89, iodine-131, and barium-140 in milk,^a July 1972

Sampling location	Concentration (pCi/liter)	
	Strontium-89	
Chile: Santiago (PAHO).....	15	
Del: Wilmington (PMN).....	7	
D.C: Washington (PMN).....	6	
Kans: Dodge City (State).....	6	
Hays (State).....	6	
Kansas City (State).....	5	
Mass: Boston (PMN).....	6	
Nebr: Omaha (PMN).....	9	
N.J: Trenton (PMN).....	6	
N.Dak: Minot (PMN).....	6	
Pa: Pittsburgh (PMN).....	11	
R.I: Providence (PMN).....	7	
S. Dak: Rapid City (PMN).....	9	

^a Iodine-131 and barium-140 were nondetectable during July 1972.

Acknowledgement

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Radiological Health Section
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Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative
Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

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Conservation

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Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health
Services

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	July-December 1970	November 1971
Carbon-14 in Total Diet and Milk	July-December 1971	May 1972
Connecticut Standard Diet	January-December 1970	December 1971
Institutional Total Diet	October-December 1971 and 1971 Annual Summary	June 1972
Radiostrontium in Milk	January-December 1970	April 1972
Strontium-90 in Tri-City Diets	January-December 1970	November 1971

Radiostrontium in milk, January-December 1971

Health and Safety Laboratory¹
U.S. Atomic Energy Commission

In 1954, the Health and Safety Laboratory began monitoring for strontium-90 in liquid whole milk to estimate the dietary contribution from the ingestion of the radionuclide from this source.

The New York City sample is a monthly composite of pasteurized milk purchased daily at

retail stores. Five main dairies are represented in the sample. The powdered milk sampling at Perry, N.Y. was terminated at the end of 1969.

The strontium-90 to calcium ratios for New York City for January-December 1971 is presented in table 1.

Recent coverage in *Radiation Data and Reports*:

Period	Issue
January-December 1970	April 1972

Table 1. Strontium-90 to calcium ratios in milk, January-December 1971

Sampling location	Strontium-90 to calcium ratio (pCi/g)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
New York, N.Y.-----	7.3	8.5	6.6	8.5	9.2	10.3	8.8	7.3	7.6	6.2	6.0	6.1

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (1). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2-4) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher

concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence¹ of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

¹ Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
Colorado River Basin	1968	March 1972
Community Water Supply Study,	1969	September 1972
Interstate Carrier Drinking Water	1971	May 1972
Kansas	January-December 1970	December 1971
Michigan	January-June 1970	November 1971
North Carolina	1968-1970	September 1972
Radioactivity in California Waters	January-December 1970	June 1972
Radioactivity in Florida Waters	1969	January 1972
Radiostrontium in Tap Water, HASL	January-June 1971	April 1972
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	January-March 1972	August 1972
Washington	July 1969-June 1970	March 1972
New York	July-December 1970 and January-June 1971	May 1972

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Gross Radioactivity In Surface Waters of the United States March 1972

Office of Air and Water Programs
U.S. Environmental Protection Agency

The monitoring of gross radioactivity in surface waters of the United States was initiated in 1957 as part of the Water Pollution Surveillance System (formerly National Water Quality Network) of the U.S. Public Health Service. Currently, the program is operated by the U.S. Environmental Protection Agency, Office of Water Programs. Regional offices of the Environmental Protection Agency are responsible for the collection of samples and the entering of the resulting data into the analytical storage and retrieval system. Radioactivity analyses are performed in the centralized radioactivity laboratories of the Office of Air and Water Programs (Cincinnati, Ohio).

The regular reporting of gross radioactivity data in *Radiological Health Data and Reports* was terminated with the publication of data for October 1968 (April 1969 issue). With the publication of data for January 1971, this activity was resumed as a monthly report series. The unpublished data for the time interval of November 1968 through December 1970 will be the subject of a future summary article.

Table 1 presents the gross alpha and beta radioactivity results for samples collected from 22 rivers and the Great Lakes during March 1972. The analytical procedures used for determining gross alpha and beta radioactivity are described in the 13th Edition of *Standard Methods for the Examination of Water and Wastewater* (1). Results are reported for the date of counting and are not corrected to the date of collection. The sensitivity in counting is that defined by the National Bureau of Standards, Handbook 86 (2) and is calculated to be <0.2 pCi/Liter for gross alpha radioactivity and <1 pCi/liter for gross beta radioactivity measurements.

REFERENCES

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- (2) U.S. DEPARTMENT OF COMMERCE. Radioactivity, Recommendations of the International Commission on Radiological Units and Measurements (1962), NBS Handbook 86 (November 29, 1963).

Table 1. Gross radioactivity in U.S. surface waters, March 1972

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
		Suspended solids	Dissolved solids	Suspended solids	Dissolved solids
Allegheny River:					
Pittsburgh, Pa.	1	<0.3	<0.6	<2	5
Animas River:					
Durango, Colo.	1	<.4	1.4	2	5
Beaver River:					
New Brighton, Pa.	1	<.4	<1.0	2	10
Cheyenne River:					
Edgemont, S. Dak.	1	3.2	3.1	25	10
Clinch River:					
Kingston, Tenn.	4	.4	.5	<2	4
		<.3	<.5	<2	6
		<.4	<.5	<2	7
		<.2	<.4	<2	9
Colorado River:					
DeBeque, Colo.	1	.8	4.4	5	15
Moab, Utah:					
Highway Bridge.	4	8.4	8.2	24	19
		5.5	6.5	28	10
		2.3	5.5	9	16
		1.0	6.8	7	18
Above Mill Creek.	4	7.5	6.1	19	11
		7.4	6.8	29	17
		2.2	3.9	14	23
		2.1	20.6	6	42
Silt, Colo.	1	.8	2.1	9	17
Cuyahoga River:					
Cleveland, Ohio.	1	<.3	<1.4	3	10
Dolores River:					
Bedrock, Colo.	5	3.6	4.5	12	9
		8.1	2.0	29	<5
		11.3	1.8	32	<4
		4.7	3.4	16	12
		2.4	3.0	8	14
Gateway, Colo.	5	7.5	10.4	25	67
		8.0	9.2	28	32
		12.8	3.6	34	9
		5.4	3.2	39	15
		3.2	3.3	11	26
Great Lakes:					
Lake Erie:					
Buffalo, N.Y.	1	<.5	<.3	<3	3
Green River:					
LaBarge, Wyo.	1	.7	1.5	6	11
Kanawha River:					
Winfield Dam, W. Va.	1	1.7	<1.1	4	4
Maumee River:					
Toledo, Ohio.	1	1.0	1.3	4	6
Mississippi River:					
Burlington, Iowa.	1	1.4	.9	3	7
Missouri River:					
Omaha, Nebr.	1	1.0	4.5	5	9
Monongahela River:					
Pittsburgh, Pa.	2	<.4	<.8	2	5
Muskingum River:					
Lock and Dam #2.	1	<.4	<2.1	2	9
North Platte River:					
Henry, Nebr.	1	<.4	16.8	7	31
Ohio River:					
Addison, Ohio.	1	1.7	<.7	9	5
Cincinnati, Ohio.	5	10.9	.6	28	2
		3.0	.9	8	2
		.6	.4	4	5
		3.7	<.5	17	8
		1.1	<.2	6	4
Hancock, W. Va.	1	.7	<1.3	2	5
Marietta, Ohio.	1	<.4	<.8	3	7
New Martinsville, W. Va.	1	.6	.8	2	4
Old Lock #19, W. Va.	1	.4	<.7	<2	4
Warwood, W. Va.	1	<.4	<.7	2	5
Platte River:					
Plattsmouth, Nebr.	1	2.9	10.3	6	27
Roanoke River:					
John Kerr Dam, Va.	4	.7	<.4	<2	2
		.5	<.4	<2	<2
		<.4	<.4	3	2
		<.2	<.2	4	6
San Miguel River:					
Uravan, Colo.	5	.6	7.7	2	11
		.3	4.5	5	12
		.8	<1.4	6	7
		.8	3.4	5	8
		<.2	1.8	4	12
Below Uravan, Colo.	5	2.6	1.18	8	26
		.6	12.0	3	27
		.5	11.0	<2	18
		<.2	6.5	3	18
		.8	18.1	4	20

Table 1. Gross radioactivity in U.S. surface waters, March 1972—continued

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
		Suspended solids	Dissolved solids	Suspended solids	Dissolved solids
San Miguel River: (cont.) Naturita, Colo.-----	5	.9 2.5 .9 <.3 <.2	5.7 3.7 1.2 1.2 1.8	4 5 4 2 4	10 8 6 11 12
St. Lawrence River: Massena, N.Y.-----	4	<.4 .7 .3 <.2	<.7 .9 .4 <.4	<2 2 2 2	4 5 5 6
Virgin River: St. George, Utah-----	1	7.9	19.1	27	36

Radioactivity in Minnesota Municipal Water Supplies¹ July 1970–June 1971

*Division of Environmental Health
Minnesota Department of Health*

The analysis of various Minnesota waters for radioactivity was initiated in 1956 as part of the Environmental Health Program in the Minnesota Department of Health. This program was expanded in 1958 to include most of the municipal surface water supplies in the State, as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, nine surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at Hallock, East Grand Forks, Eveleth, Fairmont, and St. Paul. Beginning in November 1969, weekly samples from these stations were composited and analyzed on a monthly basis. Monthly samples are taken at Crookston, International Falls and St. Cloud. Minneapolis tap water is analyzed weekly. No raw water is collected

from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross alpha and beta radioactivity. A 250-ml sample of water is evaporated into a 2-inch aluminum milk-bottle-lid planchet and counted in a proportional-gas-flow counter. The counter is calibrated with cesium-137/uranium-238 standards.

Table 1 shows a summary of the monthly average gross beta radioactivity in Minnesota municipal water supplies from July 1970–June 1971. Table 2 shows the gross alpha radioactivity in the same samples for the same period of time. Alpha concentrations reported as <1 pCi/liter were considered as 0 pCi/liter for averaging purposes.

The data obtained on gross beta radioactivity in Minnesota surface waters show a variation of concentrations with no readily apparent trends. Variations in precipitation and flow rates of streams could contribute to this fluctuation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 2 to 29 pCi/liter, which is well below the Public Health Service Drinking Water Standards (1).

¹ Data and information from "Survey of Environmental Radioactivity, July 1970–June 1971." Publication No. C00-651-86. State of Minnesota Department of Health, University Campus, Minneapolis, Minn. 55440.

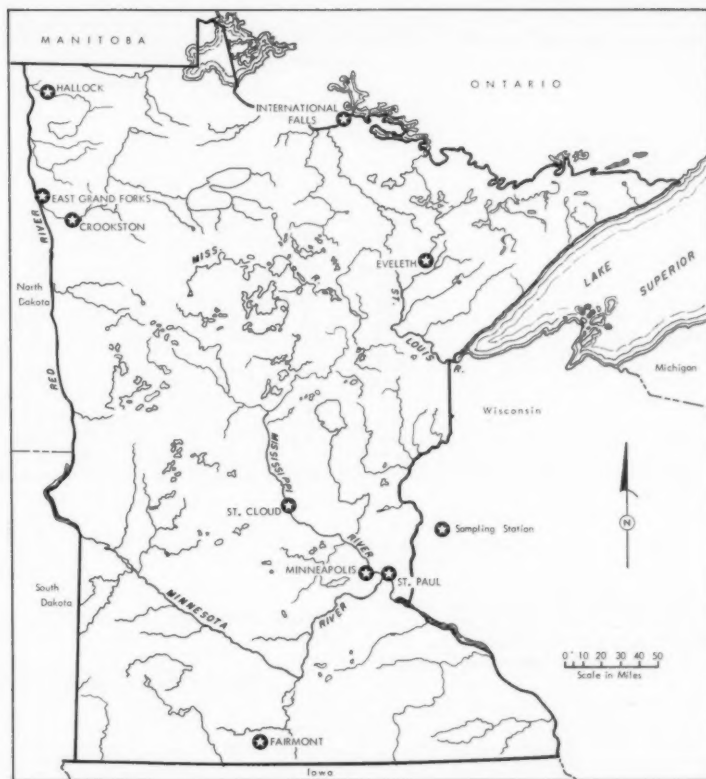


Figure 1. Minnesota surface water sampling locations

Table 1. Average gross beta radioactivity in Minnesota raw and treated water supplies, July 1970-June 1971

Town and water source	Type of water	Average concentration (pCi/liter)											
		1970						1971					
		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Crookston, Red Lake River	Raw	26	21	22	21	14	20	18	14	18	18	20	15
	Treated	20	14	17	19	14	18	18	19	14	19	14	12
East Grand Forks, Red River Lake	Raw	20	18	20	16	16	17	19	18	18	21	22	18
	Treated	12	12	9	9	6	8	6	4	6	13	8	13
Eveleth, St. Mary's Lake	Raw	13	12	12	12	9	9	10	10	8	12	11	14
	Treated	12	13	12	11	12	8	10	8	8	10	9	15
Fairmont, Budd Lake	Raw	16	11	10	11	12	9	12	9	12	11	6	14
	Treated	7	6	6	6	5	8	4	4	3	6	4	7
Hallock, Two Rivers South Fork	Raw	25	28	29	20	22	22	29	20	21	18	17	17
	Treated	10	10	9	7	6	10	10	7	8	11	10	9
International Falls, Rainey River	Raw	11	9	8	10	9	7	6	6	5	8	11	11
	Treated	10	10	8	6	6	7	6	3	4	5	9	9
Minneapolis tap water	Treated	6	5	5	4	4	5	5	4	2	6	6	6
St. Cloud, Mississippi River	Raw	NS	NS	5	NS	9	10	10	7	NS	13	11	20
	Treated	NS	NS	4	NS	4	8	5	2	NS	7	7	9
St. Paul, Vadnais Chain of Lakes	Raw	12	9	9	9	8	9	9	8	8	11	11	12
	Treated	6	7	8	4	5	4	3	3	4	5	6	7

NS, no sample.

Table 2. Average gross alpha radioactivity in Minnesota raw and treated water supplies, July 1970-June 1971

Town and water source	Type of water	Average concentration (pCi/liter)											
		1970						1971					
		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Crookston, Red Lake River.....	Raw	<5	<4	<3	<2	<3	<3	<1	<2	<2	<3	<3	<3
	Treated	<4	<3	<2	<3	<2	<2	<2	<1	<2	<2	<2	<3
East Grand Forks, Red River Lake.....	Raw	<3	<2	<2	<2	<2	<3	<2	<3	<3	<2	<5	<2
	Treated	<2	<2	<1	<1	<2	<2	<2	<2	<2	<2	<2	<2
Eveleth, St. Mary's Lake.....	Raw	<1	<3	<1	<1	<2	<3	<1	<2	<1	<1	<2	<2
	Treated	<2	<2	<1	<1	<2	<2	<1	<2	<1	<1	<2	<1
Fairmont, Budd Lake.....	Raw	8	<4	<3	<2	<3	<3	<4	<5	<3	<4	<3	<3
	Treated	<3	<2	<1	<2	<2	<2	<2	<2	<2	<2	<2	<3
Hallock, Two Rivers South Fork.....	Raw	<4	<5	<4	<4	<4	<4	5	<4	<4	<3	2	<1
	Treated	<2	<2	<2	<2	<3	<3	<1	<2	<2	2	<2	<2
International Falls, Rainey River.....	Raw	<1	<1	<1	<1	<1	1	<1	<1	<1	<2	<1	<1
	Treated	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Minneapolis tap water.....	Treated	<2	<2	<1	<2	<1	<1	<2	<1	<2	<1	1	2
St. Cloud, Mississippi River.....	Raw	NS	NS	<2	NS	<4	<4	<1	NS	NS	<2	<2	<3
	Treated	NS	NS	2	NS	<2	<2	<2	<1	NS	<1	<1	<2
St. Paul, Vadnais Chain of Lakes.....	Raw	<3	<2	<2	<2	<2	<2	<3	<2	<2	<2	<1	<2
	Treated	<3	<2	<1	<1	<1	<1	<1	<1	<2	<1	1	<2

NS, no sample

REFERENCE

- (1) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, Public Health Service Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-June 1970	November 1971

Radiostrontium in tap water July-December 1971

Health and Safety Laboratory¹
U.S. Atomic Energy Commission

The Health and Safety Laboratory has performed analyses for strontium-90 in tap water at New York City since August 1954. Samples of tap water are collected daily so that by the end of the month a composite of at least 100 liters is available for analysis. Cesium-137 determinations were begun in January 1964. The analytical methods used at the laboratory

are given in the Health and Safety Laboratory Manual of Standard Procedures (1).

Strontium-90 concentrations and cesium-137 to strontium-90 ratios in New York City tap water for July through December 1971 are presented in table 1. These results appear graphically in figure 1.

A decreasing trend has been observed in the strontium-90 concentrations since the July 1963 peak. The maximum strontium-90 concentrations observed are below the acceptable limit as set forth in the interstate carrier drinking water standards (2).

¹ Prepared from information appearing in Fallout Program Quarterly Summary Report, HASL-257 (July 1, 1972). This report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

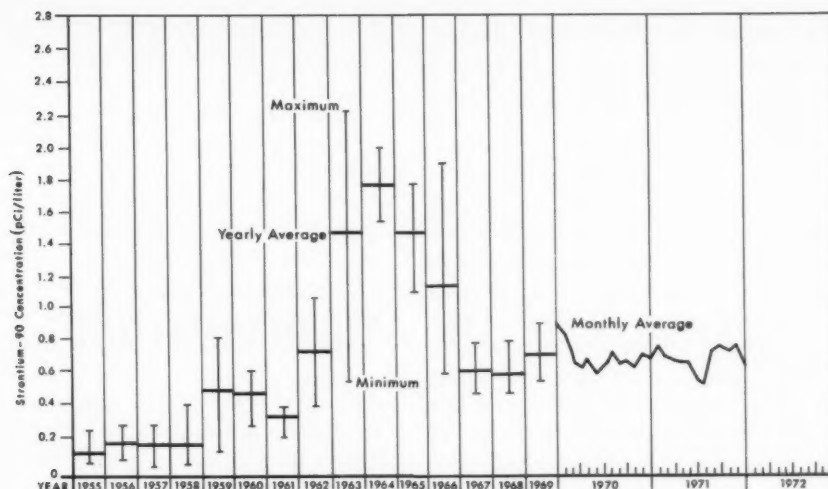


Figure 1. Strontium-90 concentrations in New York City tap water 1955-December 1971

Table 1. Radiostrontium in New York City tap water July-December 1971

Sampling months	Strontium-90 ^a	Cesium-137/ strontium-90
July.....	0.51	0.16
August.....	.72	.13
September.....	.74	.12
October.....	.72	.11
November.....	.74	.11
December.....	.61	.09

^a Approximately 100 liters per sample.

REFERENCES

- (1) U.S. ATOMIC ENERGY COMMISSION. Manual of standard procedures 40:E-38-01-16. Health and Safety Laboratory, U.S. Atomic Energy Commission, 376 Hudson Street, New York, N.Y. 10014.
- (2) FEDERAL REGISTER RULES AND REGULATIONS. Title 42-Public Health, Chapter 1, Public Health Service, Department of Health, Education and Welfare; Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards 27:2154-2155. Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (March 6, 1962).

Recent coverage in *Radiation Data and Reports*:

Period	Issue
January-June 1971	April 1972

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized peri-

odically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican National Institute of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiation Data and Reports*.

<u>Network</u>	<u>Period</u>	<u>Issue</u>
Fallout in the United States and Other Areas, <i>HASL</i>	January–December 1970	December 1971
Mexican Air Monitoring Program	January–April 1972	September 1972
Plutonium in Airborne Particulates	October–December 1971	July 1972
Surface Air Sampling Program; 80th Meridian Network, <i>HASL</i>	January–December 1969	February 1972

1. Radiation Alert Network July 1972

*Division of Atmospheric Surveillance
Environmental Protection Agency*

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 69 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate sample at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation

samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Air Quality Information Systems Branch, Division of Atmospheric Surveillance, EPA, Research Triangle Park, N.C. 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radio-logical Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by field estimate technique, during July 1972.

A high reading in a single precipitation sample of 32 nCi/m² was reported at Richmond, Va.

All other field estimates reported were within normal limits for the reporting station.



Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, July 1972

Station location		Gross beta radioactivity (5-hour field estimate) (pCi/m ³)				Precipitation			
		Number of samples	Maximum	Minimum	Average ^a	Number of samples	Total depth (mm)	Field estimation of deposition	
								Number of samples	Total deposition (nCi/m ²)
Ala:	Montgomery	20	3	0	1	3	163	3	18
Alaska:	Anchorage	2	0	0	0	0			
	Attu Island	31	1	0	0	0			
	Fairbanks	0				0			
	Juneau	0				0			
	Nome	0				0			
	Point Barrow	0				0			
Ariz:	Phoenix	19	6	0	3	0			
Ark:	Little Rock	19	2	0	1	0			
Calif:	Berkeley	20	0	0	0	0			
	Los Angeles	17	2	0	1	0			
C.Z:	Ancon	14	0	0	0	0			
Colo:	Denver	20	5	1	2	2	6	(b)	
Conn:	Hartford	20	1	0	0	7	76	7	0
Del:	Dover	19	1	0	0	0			
D.C:	Washington	27	1	0	0	0			
Fla:	Jacksonville	20	1	0	0	4	90	4	15
	Miami	0				0			
Ga:	Atlanta	12	2	1	1	0			
Guam:	Agana	0				0			
Hawaii:	Honolulu	19	0	0	0	0			
Idaho:	Boise	19	2	1	1	1	2	1	0
Ill:	Springfield	8	3	1	1	0			
Ind:	Indianapolis	18	2	0	1	0			
Iowa:	Iowa City	16	4	0	1	6	169	6	6
Kans:	Topeka	19	3	1	2	7	110	7	3
Ky:	Frankfort	2	3	1	2	0			
La:	New Orleans	18	0	0	0	13	165	(b)	
Maine:	Augusta	18	1	0	0	8	79	7	0
Md:	Baltimore	19	2	0	1	5	35	5	4
Mass:	Lawrence	18	1	0	0	5	91	5	0
	Winchester	17	2	0	1	3	39	3	0
Mich:	Lansing	19	1	0	1	7	71	7	10
Minn:	Minneapolis	13	2	0	1	7	139	7	20
Miss:	Jackson	17	2	0	1	4	67	4	0
Mo:	Jefferson City	19	4	0	1	5	52	5	0
Mont:	Helena	19	3	0	1	3	14	3	0
Nebr:	Lincoln	16	7	1	3	2	47	2	20
Nev:	Las Vegas	20	2	0	1	0			
N.H:	Concord	0				0			
N.J:	Trenton	20	2	0	0	7	82	7	2
N. Mex:	Santa Fe	16	2	0	1	0			
N.Y:	Albany	13	1	0	1	0			
	Buffalo	19	1	0	1	0			
	New York City	0				0			
N.C:	Gastonia	5	6	1	2	2	37	(b)	
N. Dak:	Bismarck	20	7	0	2	6	54	6	9
Ohio:	Cincinnati	0				0			
	Columbus	3	1	1	1	0			
	Painesville	20	2	0	1	5	67	5	15
Okla:	Oklahoma City	13	4	1	1	0			
	Ponca City	20	3	0	1	6	99	5	0
Oreg:	Portland	14	0	0	0	1	5	1	0
Pa:	Harrisburg	15	2	0	1	1	15	1	2
P.R:	San Juan	0				0			
R.I:	Providence	19	1	0	0	0			
S.C:	Columbia	15	2	0	1	5	96	4	0
S. Dak:	Pierre	20	5	1	2	0			
Tenn:	Nashville	19	2	0	1	5	148	5	10
Tex:	Austin	20	4	0	2	4	59	(b)	
	El Paso	18	3	0	1	0			
Utah:	Salt Lake City	31	2	0	1	1	1	1	0
Vt:	Barre	17	4	0	2	8	72	8	5
Va:	Richmond	17	1	0	0	2	76	2	41
Wash:	Seattle	8	0	0	0	2	16	(b)	
	Spokane	20	2	0	1	0			
W. Va:	Charleston	17	3	0	1	7	81	7	26
Wise:	Madison	20	2	0	1	8	92	8	8
Wyo:	Cheyenne	15	4	0	3	0			
Network summary		1,008	7	0	1	162	83	5	10

^a The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.^b This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,¹ July 1972

*Radiation Protection Division
Department of National Health and Welfare*

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (1-5).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

¹ Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for July 1972 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, July 1972

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m ³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m ²)
Calgary.....	5	0.1	0.0	0.1	17	1.2
Coral Harbour.....	5	.0	.0	.0	66	2.0
Edmonton.....	5	.1	.1	.1	20	1.1
Ft. Churchill.....	5	.2	.1	.1	3	.3
Fredericton.....	5	.2	.1	.1	33	2.3
Goose Bay.....	5	.1	.0	.1	21	1.2
Halifax.....	7	.2	.1	.1	37	2.2
Inuvik.....	5	.0	.0	.0	6	.2
Montreal.....	5	.1	.0	.1	14	2.1
Moosonee.....	5	.1	.0	.1	14	1.3
Ottawa.....	5	.1	.1	.1	8	1.5
Quebec.....	5	.1	.1	.1	6	.8
Regina.....	4	.1	.1	.1	24	1.5
Resolute.....	5	.0	.0	.1	173	1.6
St. John's, Nfld.....	5	.1	.0	.1	82	1.6
Saskatoon.....	5	.1	.1	.1	25	1.6
Sault Ste. Marie.....	1	.1	.1	.1	6	.4
Thunder Bay.....	5	.1	.1	.1	13	1.5
Toronto.....	5	.1	.0	.1	16	1.0
Vancouver.....	5	.1	.0	.1	20	1.6
Whitehorse.....	5	.2	.0	.1	32	2.1
Windsor.....	5	.2	.1	.1	30	1.2
Winnipeg.....	5	.1	.1	.1	18	1.1
Yellowknife.....	1	.1	.1	.1	63	2.3
Network summary...	113	0.2	0.0	0.1	31	1.4

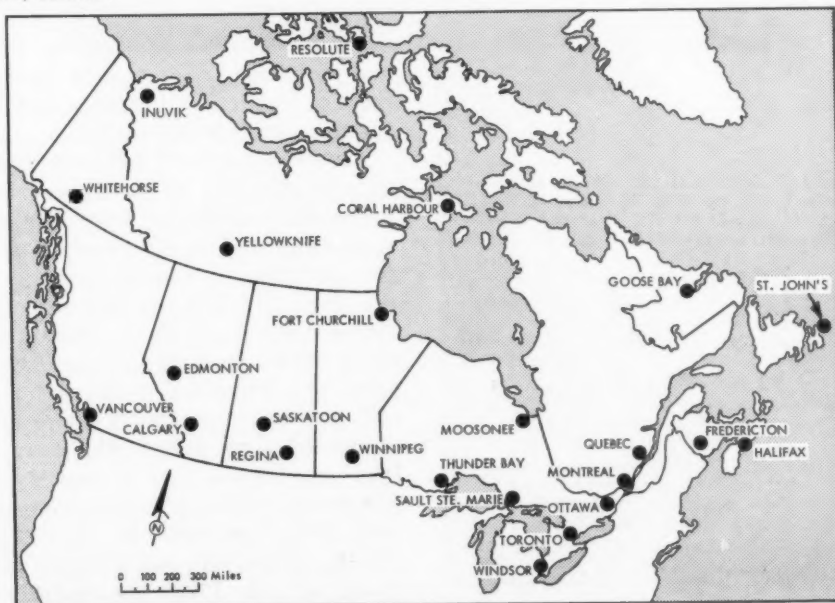


Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program July 1972

*Pan American Health Organization and
U.S. Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The July 1972 air monitoring results from the participating countries are given in table 3.



Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in
Pan American surface air, July 1972

Station location	Number of samples	Gross beta radioactivity (pCi/m ³)		
		Maximum	Minimum	Average ^a
Argentina: Buenos Aires.....	0			
Bolivia: La Paz.....	3	0.04	0.03	0.03
Chile: Santiago.....	29	17.85	.02	1.39
Colombia: Bogota.....	20	.02	.00	.01
Ecuador: Cuenca.....	5	.02	.00	.01
Guayaquil.....	14	.44	.02	.13
Quito.....	21	.02	.00	.00
Guyana: Georgetown.....	2	.03	.01	.02
Jamaica: Kingston.....	0			
Peru: Lima.....	0			
Venezuela: Caracas.....	5	.11	.01	.05
West Indies: Trinidad.....	0			
Pan American summary.....	99	17.85	0.00	0.43

^a The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging 0.00 pCi/m³.

^b Activity identified as barium-140, lanthanum-140, iodine-131, ruthenium-103, zirconium-niobium-95.

4. California Air Sampling Program July 1972

*Bureau of Radiological Health
California State Department of Public Health*

The Bureau of Radiological Health of the California State Department of Public Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 4.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Public Health where they are analyzed for their radioactive content.

Airborne particles are collected by a continuous sampling of air filtered through a 47 millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends. The filters are analyzed for gross alpha and beta radioactivity 72 hours after the end of the collection period. The daily samples are then composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. Table 4 presents the monthly gross beta radioactivity in air for the month of July 1972. The monthly sample results are presented quarterly.



Figure 4. California air sampling program stations

Table 4. Gross beta radioactivity in California air,^a July 1972

Station location	Number of samples	Gross beta radioactivity ^b (pCi/m ³)		
		Maximum	Minimum	Average
Bakersfield	31	0.81	0.12	0.35
Barstow	31	.70	.14	.33
Berkeley	31	.32	.01	.13
Colfax	31	.60	.10	.29
El Centro	31	1.00	.06	.24
Eureka	31	.18	.03	.07
Fresno	31	.75	.14	.31
Los Angeles	31	.39	.02	.16
Redding	31	.54	.12	.29
Sacramento	31	.56	.08	.21
Salinas	31	.58	.06	.25
San Bernardino	31	.89	.12	.30
San Diego	31	.40	.08	.18
Santa Rosa	30	.47	.00	.14
Summary	433	1.00	0.00	0.23

^a Daily alpha levels are available for Berkeley and Los Angeles. Monthly averages are 0.1 and 0.1 pCi/m³, respectively.

^b Samples taken at Orange, Calif., July 7 and 21, 1972 resulted in a gross beta activity of 0.30 and 0.10, respectively which resulted in a summary of 0.20.

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- (4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).
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Air Surveillance Network, July 1972

National Environmental Research Center-Las Vegas¹, Environmental Protection Agency

The Air Surveillance Network (ASN), operated by the National Environmental Research Center-Las Vegas (NERC-LV), consists of 104 active and 18 standby sampling stations located

¹ Formerly the Western Environmental Research Laboratory.

² The ASN is operated under a Memorandum of Understanding (No. AT(26-1)-539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

in 21 western States (figures 1 and 2). The network is operated in support of nuclear testing sponsored by the Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), by the Space Nuclear Systems Office at the Nuclear Rocket Development Station which lies within the NTS, and by the AEC at any other designated testing sites.²

The stations are operated by State health

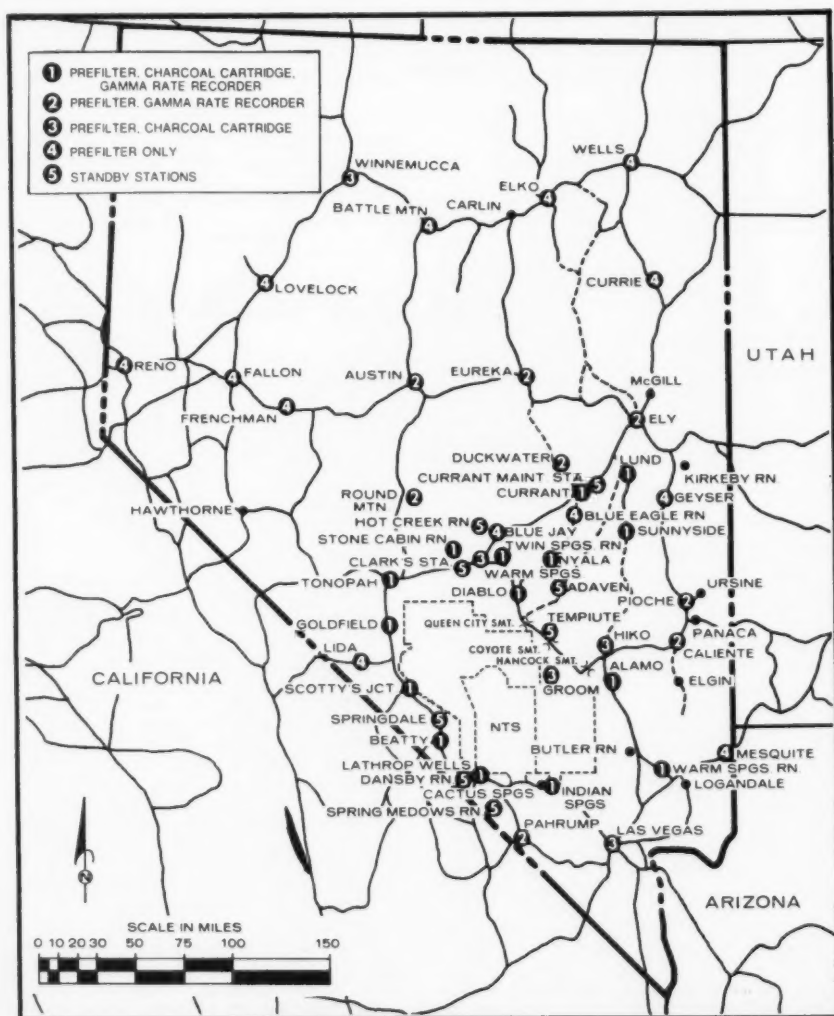


Figure 1. NERC-LV Air Surveillance Network stations in Nevada

Table 1. Summary of gross beta radioactivity concentrations in air,
July 1972

Location		Number of samples	Concentration (pCi/m ³)		
			Maximum	Minimum	Average ^a
Ariz:	Kingman	31	0.4	<0.1	0.1
	Phoenix	31	.2	<.1	.1
	Seligman	31	.5	<.1	.2
	Winslow	31	.5	<.1	.1
Ark:	Little Rock	20	.4	<.1	.2
Calif:	Baker	29	.4	.1	.2
	Barstow	31	.7	<.1	.2
	Bishop	31	.4	<.1	.2
	Death Valley Junction	31	.6	<.1	.3
	Furnace Creek	29	.4	<.1	.2
	Indio	30	.3	<.1	.2
	Lone Pine	30	.5	<.1	.2
	Needles	24	.3	<.1	.2
	Ridgecrest	31	.5	<.1	.2
	Shoshone	30	.3		.2
Colo:	Denver	20	.4	.1	.2
	Durango	31	.4		.2
Idaho:	Boise	31	.7	<.1	.3
	Idaho Falls	20	.6	.1	.3
	Preston	31	.6	.1	.3
	Twin Falls	31	.6	.1	.3
Iowa:	Iowa City	19	.3	<.1	.2
	Sioux City	17	.5	<.1	.2
Kans:	Dodge City	31	.4	<.1	.2
La:	Lake Charles	19	.6	.1	.1
	Monroe	17	.8	<.1	.2
	New Orleans	19	.7	<.1	.2
	Minneapolis	17	.4	.1	.2
Minn:	Joplin	31	.6	.1	.2
	St. Joseph	31	.5	<.1	.2
Nebr:	St. Louis	30	.4	<.1	.2
	North Platte	25	.3	<.1	.2
Nev:	Alamo	31	.4	<.1	.2
	Austin	20	.4	.1	.3
	Battle Mountain	31	.5	.1	.3
	Beatty	31	.4	.1	.2
	Blue Eagle Ranch (Currant)	29	.6	<.1	.3
	Blue Jay	31	.7	<.1	.2
	Caliente	30	.5	<.1	.2
	Currant Ranch	31	.5	<.1	.2
	Currie	31	.7	<.1	.3
	Diablo	32	.4	<.1	.2
	Duckwater	25	.4	<.1	.2
	Elko	31	.6	<.1	.3
	Ely	29	.5	.1	.2
	Eureka	31	.5	<.1	.2
	Fallini's Twin Springs Ranch	32	.5	<.1	.3
	Fallon	30	.5	<.1	.3
	Frenchman Station	31	.4	<.1	.2
	Geyser Maintenance Station	31	.6	<.1	.2
	Goldfield	31	.5	<.1	.2
	Groom Lake	31	.8	<.1	.2
	Hiko	30	.9	<.1	.3
	Indian Springs	31	.5	<.1	.2
	Las Vegas	20	.3	0.1	.2
	Lathrop Wells	28	.7	<.1	.2
	Lida	31	.4	<.1	.2
	Lovelock	31	.7	.1	.3
	Lund	31	.4	<.1	.2
	Mesquite	31	.4	<.1	.2
Nyala	31	.5	<.1	.2	
Pahrump	11	.2		.1	
Pioche	29	.4	<.1	.2	
Reno	32	.5	.1	.3	
Round Mountain	30	.5	<.1	.2	
Scotty's Junction	30	.6	<.1	.2	
Stone Cabin Ranch	30	.5	<.1	.2	
Sunnyside	25	.5	<.1	.2	
Tonopah	31	.5	<.1	.2	
Tonopah Test Range	18	.4	.1	.2	
Warm Springs	31	.4	<.1	.2	
Warm Springs Ranch	27	.4	<.1	.2	
Wells	31	.7	<.1	.3	
Winnemucca	31	.6	<.1	.3	
N. Mex:	Albuquerque	22	.5	<.1	.2
	Carlsbad	30	.2	<.1	.1
Okla:	Muskogee	30	.4	.1	.2
Oreg:	Burns	31	.5	<.1	.3
	Medford	26	.4	.1	.2
S. Dak:	Aberdeen	31	.7	<.1	.2
	Rapid City	30	.4	<.1	.2
Tex:	Abilene	29	.3	<.1	.1
	Amarillo	30	.3	<.1	.1
	Austin	19	.2		.1
	Fort Worth	30	.4	<.1	.2

See footnotes at end of table.

Table 1. Summary of gross beta radioactivity concentrations in air
July 1972—continued

Location	Number of samples	Concentration (pCi/m ³)		
		Maximum	Minimum	Average*
Utah: Bryce Canyon	28	.4	<.1	.2
Cedar City	30	.5	.1	.2
Delta	31	.7	<.1	.3
Dugway	31	.7	<.1	.3
Enterprise	31	.3	<.1	.2
Garrison	31	.6	<.1	.3
Logan	31	.6	<.1	.3
Milford	31	.4	<.1	.2
Monticello	12	.4	<.1	.3
Parowan	28	.6	<.1	.2
Provo	30	1.2	<.1	.3
Roosevelt	30	.5	.1	.2
Salt Lake City	31	.5	<.1	.2
St. George	30	.4	<.1	.2
Wendover	30	.7	<.1	.3
Wash: Seattle	21	.3	<.1	.1
Spokane	20	.4	<.1	.2
Wyo: Rock Springs	21	.4	<.1	.2
Worland	31	.7	<.1	.2

* Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported as <0.1.



Figure 2. NERC-LV Air Surveillance Network stations outside Nevada

department personnel and by private individuals on a contract basis. Daily 24-hour samples are collected at each station. All samples are mailed to the NERC-LV unless special retrieval is arranged at selected locations in support of known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports*.

Results

Table 1 presents the monthly average gross beta radioactivity in air particulates for each of the network stations. The minimum reported concentration for gross beta is 0.1 pCi/m^3 ; however, gross beta concentrations above the minimum detectable concentration of 0.06 pCi/m^3 are used in determining averages. Individual concentrations which are below the

minimum detectable concentration are assumed to be equal to the minimum detectable concentration. Averages less than the minimum reported level are reported as $<0.1 \text{ pCi/m}^3$. The highest gross beta concentration within the network on a single filter during July was 1.2 pCi/m^3 at Provo, Utah.

From gamma spectrometry results, zirconium-95 was identified on samples collected in Minnesota and Nevada. The highest concentration was 0.2 pCi/m^3 at Elko, Nev. This radionuclide is attributed to foreign atmospheric testing.

Copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA regional offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC-LV upon written request.

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained

from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation stand-

ards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."¹

Summaries of the environmental radioactivity data follow for S1C Prototype Reactor Facility and Shippingport Atomic Power Station.

¹ Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. S1C Prototype Reactor Facility² January–December 1970

*Combustion Engineering, Inc.
Windsor, Conn.*

The S1C Prototype Reactor Facility is a land-based nuclear submarine power plant operated for the Atomic Energy Commission by the Naval Reactors Division of Combustion Engineering, Inc. (figure 1). The prototype contains a pressurized water reactor power plant which is primarily used to train personnel in the operation of naval reactor power plants. Reactor power operations at the S1C Prototype Facility began in December 1959.

The low level radioactive waste discharged intermittently from S1C prototype operations consists mainly of water. Small quantities of airborne particulates in gaseous waste are also generated and released on occasion in the venti-

lation exhaust air.

Essentially, all of the radioactive waste originates from the activation of minute amounts of impurities or corrosion products in the circulating water used as a reactor coolant. All materials released to the environment are rou-

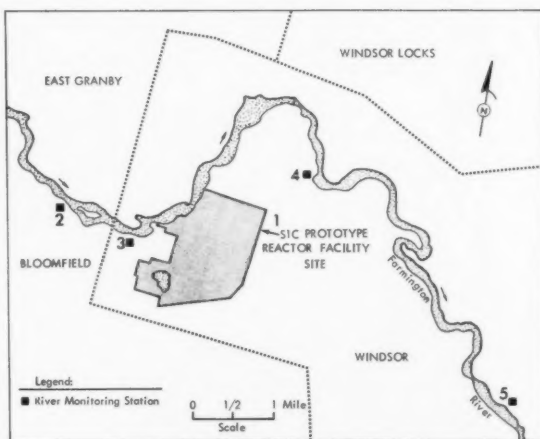


Figure 1. Environmental monitoring locations, S1C Prototype site

² Summarized from "S1C Prototype Reactor Facility Environmental Monitoring Report for 1970".

tinely monitored to assure that waste disposal operations comply with AEC regulations.

Liquid radioactive waste

Drainage from all systems which are known to contain radioactive liquids were collected, processed and sampled prior to discharge to the environment to assure that discharge concentrations were within the required limits. In addition, waste effluent is sampled as it is discharged to the environment and results indicated that concentrations were within the required limits.

The S1C Prototype discharged a total of 1.99 megaliters of radioactive liquid waste containing 457.8 microcuries of radioactivity during 1970 for an annual average discharge concentration of 230 pCi/liter.

Water monitoring

Water and sediment samples from the Farmington River are taken quarterly and analyzed. These samples are used to determine if buildup (reconcentration of radioactivity) is occurring.

Results of sampling of the Farmington River during 1970 are shown in table 1. During 1970, gross gamma radioactivity of water samples from the outlet of the S1C discharge brook was well below the 30 nCi/liter maximum permissible concentration specified by the Federal Regulations for cobalt-60, the most limiting radionuclide in S1C wastes.

Table 1. Gross gamma radioactivity in Farmington River 1970

Period (1970)	Number of samples	Gross gamma concentration (pCi/liter)	Range of gross gamma concentration (pCi/liter)
January-March.....	(*)		
April-June.....	3	120	80-180
July-September....	3	130	89-210
October-December..	3	94	80-93

* Sample not taken because of ice on river.

Results of the analysis of sediment samples taken at the outflow of the S1C Prototype discharge brook are contained in table 2.

Table 2. Farmington River sediment sample results, 1970

Period (1970)	Number of samples	Gross gamma concentration (pCi/liter)	Range of gross gamma concentration (pCi/liter)
January-March.....	(*)		
April-June.....	3	2.4	1.5-2.9
July-September....	3	2.9	1.9-4.6
October-December..	3	2.5	2.0-3.4

* Sample not taken because of ice on river.

Airborne radioactivity

All areas onsite where gaseous and/or particulate airborne radioactivity could be present are directed through ducts to monitored stacks. The stacks are monitored for airborne levels on a continuous basis.

The airborne particulate radioactivity samples taken during discharge are monitored again after allowing short-lived radioactivity from natural radon decay products to decay. During 1970, the total particulate radioactivity released from the S1C site was less than 0.0063 curies.

Radiation evaluation

Film badges were posted on the site's exclusion area perimeter for the detection of beta-gamma radiation. The badges were processed monthly and the exposure results were generally less than 10 millirem. The normal background for the surrounding area not influenced by S1C Prototype operation is also 10 millirem per month.

Conclusions

Results of the analyses and of the continuous monitoring throughout 1970 have indicated that S1C Prototype operations have met all of the Federal Regulations pertaining to AEC standards. Environmental analyses indicate that no significant quantities of radioactivity have accumulated above the preoperational environmental results. It is, therefore, concluded that the facility operations have not adversely affected the surrounding environment.

Recent coverage in *Radiation Data and Reports*.

Period	Issue
January-December 1969	December 1970

2. Shippingport Atomic Power Station³ January–December 1970

*Duquesne Light Company
Shippingport, Pa.*

The Shippingport Atomic Power Station is located on the south bank of the Ohio River in a site consisting of over 400 acres. The site is about 25 miles west of Pittsburgh and about 11 miles below the confluence of the Beaver and Ohio Rivers (figure 2). The station is designed to produce electric energy by a conventional central station type turbine-generator unit. The pressurized water reactor consists of a closed system in which water is circulated by pumps over an array of nuclear fuel elements, or core, contained in a reactor vessel, to heat exchangers where steam is formed in a separate isolated system.

Radioactive waste handled under the environmental program includes liquid and gaseous effluents released into the Ohio River and atmosphere, respectively. The levels of radioactivity released were below Shippingport discharge limits. These limits are based upon radiation standards set forth by AEC's division of Operational Safety in directives pub-

lished in the AEC Manual,¹ and a waste discharge permit from the Pennsylvania Sanitary Water Board.

Liquid radioactive waste

The liquid radioactive wastes disposed of at Shippingport are primarily from the reactor coolant system. The radioactive waste produced by the plant is reduced in concentration in such a manner that the concentration of these wastes in water measured at the condenser water stream, before discharge to the Ohio River, meets the limits as delineated above. In order to assure that the liquid discharged from the plant will meet specified tolerances, all radioactive waste is collected, processed, and sampled prior to discharge to the environment.

During 1970, a total of 71 mCi gross beta-gamma radioactivity in the liquid waste (exclusive of tritium) and 1.72 Ci of tritium in liquid waste were released into the environment. The average daily discharge of tritium during this period was 4.7 mCi. All reported concentrations released to the environment were well below those specified by State and Federal regulations.

³ Summarized from Environmental Radioactivity at the Shippingport Atomic Power Station for the Calendar Year 1970."

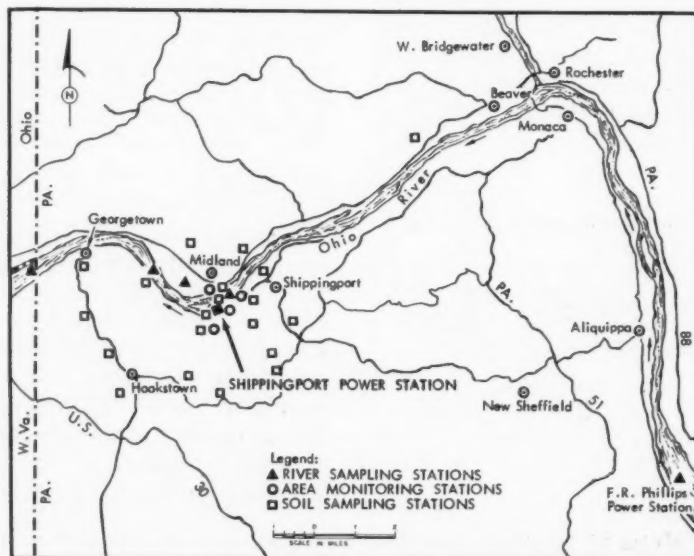


Figure 2. Shippingport power station sampling locations

Table 3. Gross radioactivity in the Ohio River, Shippingport Atomic Power Station, January-December 1970

Type of radioactive material	Average concentration (pCi/liter)							
	Influent samples				Effluent samples			
	Jan-Mar	Apr-June	July-Sept	Oct-Dec	Jan-Mar	Apr-June	July-Sept	Oct-Dec
Alpha:								
Total solids.....	1.08	1.92	1.98	5.36	1.09	1.06	1.14	2.43
Beta:								
Total solids.....	1.12	21.8	16.7	17.4	8.8	15.3	10.9	10.1
Potassium-40.....	3.5	5.4	6.4	4.8	3.6	5.3	6.4	4.8

Ohio River water analysis

During 1970, weekly composite samples were obtained from two continuous automatic samplers in the station circulating water line upstream and downstream of the radioactive water effluent. Both suspended and dissolved materials in the composite samples were analyzed for gross alpha and beta-gamma radioactivity. Each composite is also analyzed for potassium-40 content. No significant difference was observed among the average alpha, beta-gamma, and potassium-40 radioactivity for the influent and effluent samples. The results of these analyses are presented in table 3.

Ohio River sediment analysis

Once during each calendar quarter, sediment samples of the Ohio River were collected upstream and downstream of the circulating water outfall with a Birge-Ekman dredge. These samples were quantitated assuming all detected radioactivity to be cobalt-60, which is the major constituent of radioactive contamination at the station. The results of the sediment samples are presented in table 4. These data indicate that there was no increase of radioactivity in the river sediment as a result of the station's discharges.

Table 4. Total radioactivity in the Ohio River sediment samples, Shippingport, January-December 1970

1970	Number of samples	Gross radioactivity (pCi/g)	
		Upstream	Downstream
January-March.....	2	16.1	18.5
April-June.....	2	10.4	18.1
July-September.....	2	16.0	12.0
October-December.....	2	9.3	7.6

Gaseous radioactive waste

Gaseous discharges to the atmosphere, identified as xenon-133, are controlled and released at concentrations less than the AEC standard of 300 nCi/m³. During the year 1970, a total of 19 microcuries of xenon-133 were released from the plant site at less than the specified concentration.

Film badge monitoring

Twelve film badges for detecting beta-gamma radioactivity were posted continuously at the site perimeter in an attempt to determine the external radiation exposure in the immediate area. In order to accomplish this, a control film badge location was established at a point 10 miles from the station boundary.

The density of the offsite monitoring film was not measurably different from the control film. This indicates that the film exposure at all locations averaged <0.03 mrem/h for each month of 1970 which is considered normal background radiation for this area. These results show that radiation exposure to the general public outside the station was not above that received from natural background radiation levels.

Fallout

Precipitation and fallout are collected in a high-walled pot at one location on the site and analyzed monthly for gross alpha and beta radioactivity. A summary of the quarterly average fallout results for 1970 is presented in table 5.

**Table 5. Radioactivity in fallout, Shippingport
January-December 1970**

1970	Deposition rate (nCi/m ² -month)	
	Alpha radio- activity	Beta radio- activity
January-March.....	0.32	8.64
April-June.....	.51	36.90
July-September.....	.85	12.96
October-December.....	.31	8.65
12-month average.....	0.49	16.83

Conclusion

From the data presented above, it may be concluded that during 1970 the radioactive effluent released from the Shippingport Station site did not cause any significant increase in background radiation levels. In this regard, the station procedures relative to controlling radioactive discharges to the environment are considered to be effective in protecting the health and safety of the general public.

Recent coverage in *Radiological Health Data and Reports*.

Period	Issue
January-December 1969	November 1970

Reported Nuclear Detonations, October 1972

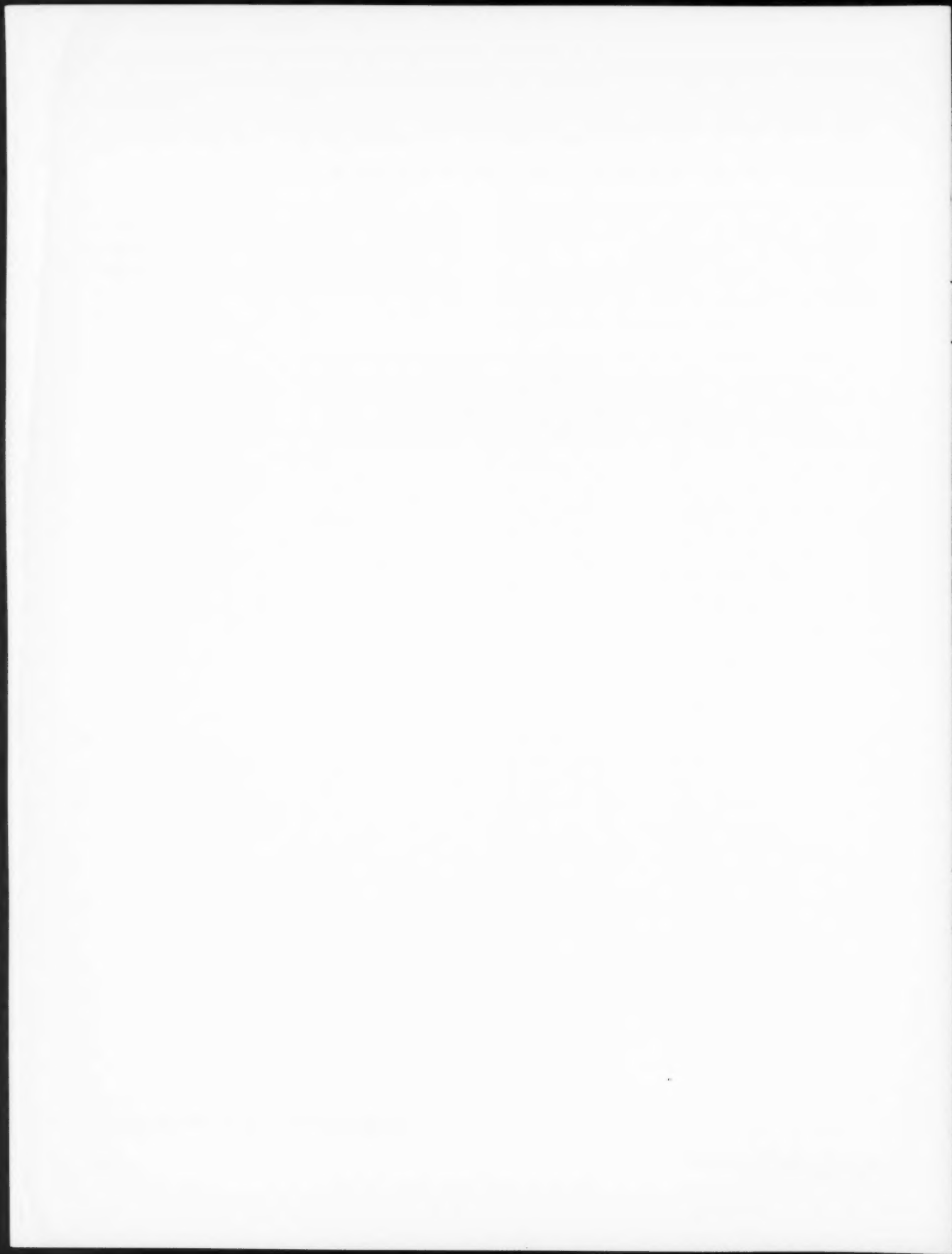
(Includes seismic signals presumably from foreign nuclear detonations)

There were no United States nuclear detonations reported by the U.S. Atomic Energy Commission in October 1972.

The U.S. Atomic Energy Commission announced that the United States recorded

seismic signals, presumably from a Soviet underground nuclear explosion, on October 3, 1972. The signals originated south of Volgograd and were equivalent to those of an underground explosion of 200 kilotons to 1 megaton.

Information in this section is based on data received during the month, and is subject to change as additional information may become available. Persons requiring information for purposes of compiling announced nuclear detonation statistics are advised to contact the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.



SYNOPSIS

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL RADIOACTIVITY IN ILLINOIS, 1970. Moshe J. Shmuklarsky. Radiation Data and Reports, Vol. 13, November 1972, pp. 589-618.

The contribution of radioactivity to the Illinois environment during 1970 resulting from the operation of nuclear power plants and from other major natural and manmade sources is presented. The environmental surveillance programs of the Dresden, Quad-Cities and Zion nuclear power stations are described. Dresden Unit 1 radioactive gaseous and liquid releases for the past 11 years, and Dresden Unit 2 discharges for 1970 are summarized. On the basis of data gathered during 1970, it is concluded that the effect of nuclear power plant operations on the radioactivity level of most environmental media was hardly distinguishable from the natural and fallout radioactivity. The only measured environmental radiation effect of nuclear power generation within the State was an apparent increase of a few millirem per year in the external background exposure in the vicinity of Dresden-1.

KEYWORDS: Illinois, environment nuclear power, radioactivity, reactors, Dresden, Quad-Cities, Zion, x-ray, cosmic rays, terrestrial.

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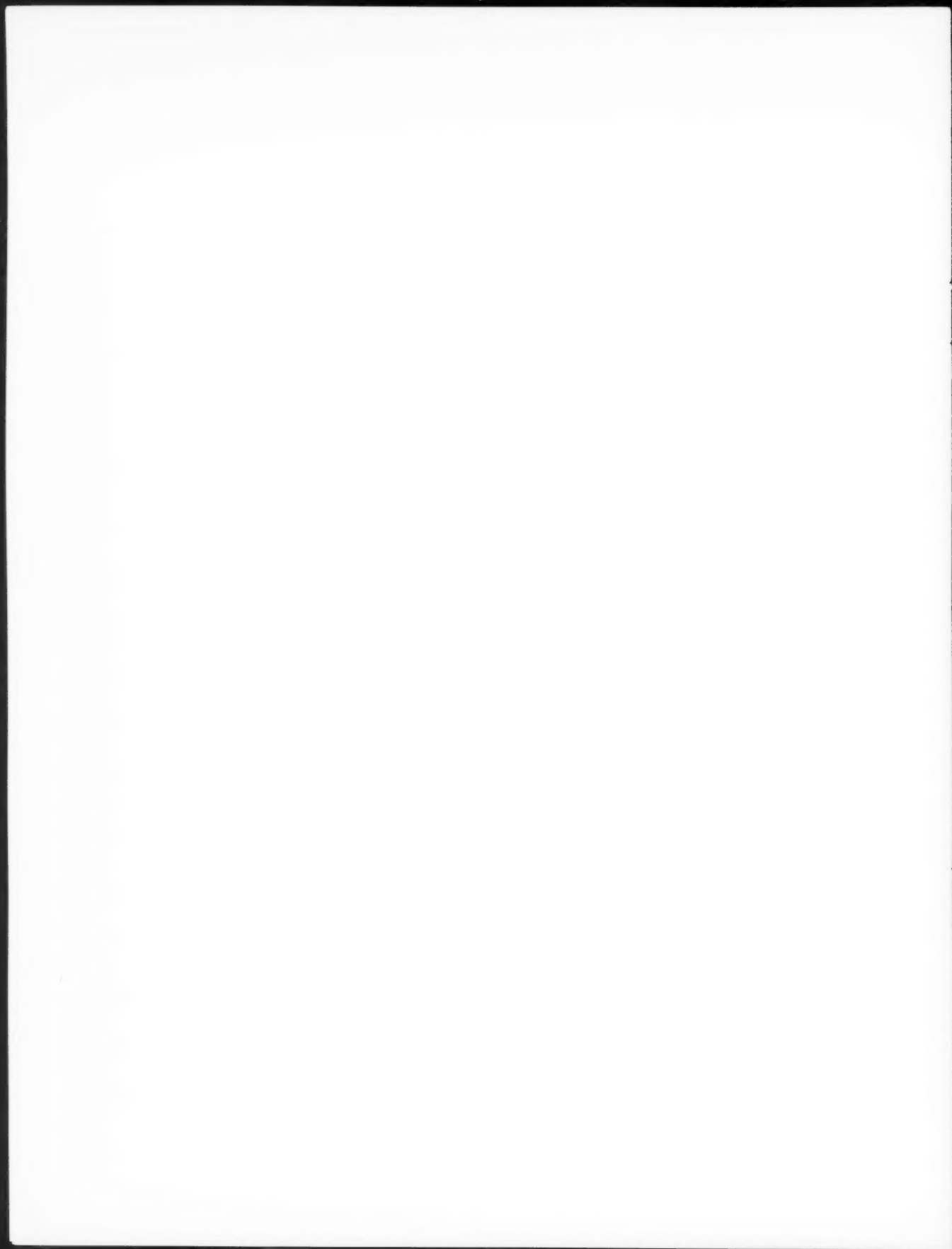
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November 1972



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